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Articles

Book Reviews

Reader's Forum

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In This Issue

The usefulness of economic data, therefore, cannot be gauged without relating them to the uses (theorems) to which they are to be fitted. Oskar Morgenstern (1963)

In an information age, it is increasingly important that we not confuse data with information. Information is data that is placed within a particular context. It is the context and underlying conceptual framework that make the data useful in decision-making. Without the context and framework, the value of data is indeterminate. Agricultural economists are often the vital link in producing useful information out of data and defining what data are needed to produce information.

Bruce Gardner, in his recent article in the *Journal of Economic Literature*, "Changing Economic Perspectives on the Farm Problem," emphasizes the role of the data in identifying and rejecting unsound theories. He identifies his review as "a case study of the uses of theory and data in applied economics." Gardner argues that economists need to pay closer attention to the linkage between data and theory. This is analogous to Morgenstern's maxim that "there can be no measurement without theory." In essence, data, theory, and context are inextricably joined in producing information.

Constructing a framework and establishing a context for data are what we do as economists, and in fact are primary objectives of our journal. The three articles in this issue are good examples of the value added to data by agricultural economists.

In the lead article, Weiss launches a primer on contemporary risk concepts. The classical expected utility model has been under attack in recent years because an accumulation of empirical evidence conflicts with predicted behavior. The theory is slowly evolving to less restrictive models that permit greater flexibility in functional forms and allow empirical behavior greater scope in telling its own story. Many agricultural and applied economists have hesitated to explore these newer models because of the daunting mathematical language used for exposition. Weiss carefully develops the underlying framework of this complex subject and discusses the advanced mathematical tools necessary to explore these contemporary risk concepts. He captures the newcomer's interest by providing examples of contemporary risk theory emerging as a fruitful model for explaining behavior. He cites areas in commodity futures and options, commodity price stabilization, information models, and measurement of risk attitudes. Given the critical research needs in these areas, this article provides an initial look at some challenging new theoretical developments.

Sparks and Ward quantify the growing international market for fresh vegetables. Abstracting from the voluminous detail that sometimes hides the broad, sweeping market forces, Sparks and Ward examine aggregate fresh vegetable trade among eight major trading regions. The estimated model is then used to investigate the potential impact of the North American Free Trade Agreement (NAFTA) on trade between Canada and the United States. Sparks and Ward contend that NAFTA will increase Canadian demand for U.S. vegetables more than U.S. demand for Canadian vegetables in absolute terms but slightly less so in percentage terms.

Denbaly and Torgerson estimate the macroeconomic elasticities of the relative wheat price, measuring the magnitudes of shortrun deviations from longrun equilibrium and the speed with which the relative price approaches its longrun equilibrium level. The relative wheat price is modeled using a cointegration methodology that joins the longrun trend relationship between the relative price and its determinants, including macroeconomic variables, into a shortrun dynamic equation. The new methodology resolves two difficulties in estimating the elasticities of relative prices with respect to macroeconomic variables: dynamics and endogeneity of macroeconomic variables. They find that in periods of expansionary monetary policy, wheat prices overshoot their longrun equilibrium value, disproportionately benefiting wheat producers relative to noncommodity sectors.

Stanton, Jinkins, Ahearn, and Hanson address the issue of measuring farm size and structure. They argue that the most appropriate economic measure of farm size for addressing any policy issue is by means of value-added statistics. While gross sales are a convenient and common measure of farm size, they argue that net value-added provides a clearer and sometimes quite different picture of the economic contribution of farms.

In the first of four book reviews, Richard Foote explores *Economic Models, Estimation, and Socioeconomic Systems: Essays in Honor of Karl Fox.* Dr. Foote, an esteemed colleague of Fox, concentrates

on the essays he believes would have the most appeal to readers of *JAER*. Foote highly recommends essays by, among others, Christ and Breimyer. He suggests that all libraries purchase the book but recommends that individuals borrow a copy, read articles of interest, and then decide whether to add to one's personal library.

Burt Sundquist gives high marks to *Bovine Somatotropin and Emerging Issues*, edited by Milton Hallberg. Sundquist indicates that the book "presents a much better integrated treatment of bST than is available elsewhere." He goes on to say that in his judgment the book provides a very useful prototype for broad-based technology assessment studies which public research institutions should undertake. Moreover, Sundquist recommends the book be read by a wide audience, not just agricultural economists.

Gene Mathia writes that the dominant focus of *Agriculture and the State—Growth, Employment, and Poverty of Developing Countries*, edited by C. Peter Timmer, is on the success of some common forms of government intervention. He notes that as a research document the book has limited usefulness, but the insights of the various authors, many of whom are seasoned veterans of development analysis or actual participants in the development process, make the book useful to policymakers.

Kuo Huang indicates *Food Trends and the Changing Consumer* by Senauer, Asp, and Kinsey serves best as an introduction to food consumption research without much attention paid to exploring methodological issues. Researchers would find the book useful for a general understanding of major factors that affect food choices and as a useful reference source for food safety and other current food and nutrition policy issues. Overall, Huang finds the book well written and targeted at readers interested in gaining a general understanding of consumer trends, food consumption, and the food industry.

In keeping with our theme of developing new information by providing both a context and framework, we are adding a new feature to *JAER*. "Reader's Forum" is designed to give our readers a vehicle for expressing views, opinions, comments, and ideas on a wide range of topics in agricultural economics and related but sometimes farflung fields. The forum can include invited essays, solicited and unsolicited commentary, review articles, and methodological pieces. Usual peer review procedures will not apply, but the editors reserve the right to decide the appropriateness of any paper. We welcome your proposals, suggestions, and commentary.

The first essay to appear in the forum is Gerald Vaughn's support of Otto Doering's call for nonmarginal analysis. Doering, in an invited essay in Vol. 43, No. 1 of *JAER*, argued that marginal analysis, the mainstay of much of the economics profession, is becoming less and less useful and the development of nonmarginalist economics needs to be accelerated to meet public policy needs. Vaughn supports this position and expands upon Doering's arguments. Any marginalists care to take exception?

James Blaylock
David Smallwood

Beyond Expected Utility: Risk Concepts for Agriculture from a Contemporary Mathematical Perspective

Michael D. Weiss

Abstract. *Expected utility theory, the most prominent economic model of how individuals choose among alternative risks, exhibits serious deficiencies in describing empirically observed behavior. Consequently, economists are actively searching for a new paradigm to describe behavior under risk. Their mathematical tools, such as functional analysis and measure theory, reflect a new, more sophisticated approach to risk. This article describes the new approach, explains several of the mathematical concepts used, and indicates some of their connections to agricultural modeling.*

Keywords. *Individual choice under risk, expected utility theory, risk preference ordering, utility function on a lottery space, Fréchet differentiability, random function, random field.*

In their attempts to model individual behavior under risk, agricultural economists have relied heavily on the expected utility hypothesis. This hypothesis stipulates that individuals presented with a choice among various risky options will choose one that maximizes the mathematical expectation of their personal "utility." An accumulation of evidence reported in the literatures of both economics and psychology, however, has by now clearly demonstrated that expected utility theory exhibits serious deficiencies in describing empirically observed behavior. (For reviews, see Schoemaker, 1982; Machina, 1983, 1987; Fishburn, 1988.)[1] As a result, economists and psychologists have been formulating and testing new theories to describe behavior under risk. These theories do not so much deny classical expected utility theory as generalize it. By imposing weaker restrictions on the functional forms used in risk models, they allow empirical behavior more scope in telling its own story.

To a significant extent, this search for a new paradigm of behavior under risk is being conceived and conducted in the spirit and language of contemporary mathematics. The concepts being employed, such as the derivative of a functional with respect to a probability distribution or vector spaces whose "points" are functions, cannot be reduced to the graphical analysis traditionally favored by applied economists. Rather, they involve a genuinely new approach, a way of thinking that is at the same time more precise and more abstract.

This article is intended to provide agricultural and applied economists with an introduction to these newer ways of thinking about behavior under risk. Designed to be largely self-contained, the article first sketches some prerequisites from set theory and measure theory, then defines and discusses several key risk concepts from a modern perspective.

On the surface, the mathematical ideas we describe may appear distant from direct practical application. Yet, they already play an important role in various theories on which practical applications have been or can be based. Some examples:

- **Commodity futures and options.** A revolution in the theory of finance, begun in the 1970's and continuing today, has been brought about by the adoption of advanced mathematical tools, such as continuous stochastic processes, the Black-Scholes option pricing formula, and stochastic integrals (used to represent the gains from trade). The insights afforded by these methods have had a substantial practical impact on securities trading. Understanding commodity futures and options trading in this new environment requires greater familiarity with the new mathematical machinery. This machinery, in turn, draws heavily on measure theory, which is now a prerequisite for advanced finance theory (Dothan, 1990; Duffie, 1988).

- **Commodity price stabilization.** In recent years, economists increasingly have drawn on the techniques of stochastic dynamics to analyze the behavior of economic processes over time. Applications of stochastic dynamics range from the optimal management of renewable resources, such as timber, to optimal firm investment strategies. For agricultural

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Weiss is an economist with the Commodity Economics Division, ERS. The author thanks the editors and reviewers for their comments.

[1]Sources are listed in the References section at the end of this article.

economists, a particularly important application is the construction of policy models of commodity price stabilization (Newbery and Stiglitz, 1981). Such models often portray a stochastic sequence of choices by both producers and policymakers. In every time period, each side must confront not only uncertain future prices and yields, but the uncertainties of the other's future actions. An understanding of this subject requires concepts of dynamics, probability, and functional analysis.

Modern treatments of stochastic dynamics (Stokey and Lucas, 1989) couch their explanations in the language of sets and functions. We describe and use this language in this article. We also describe Fréchet differentiability, a generalization of ordinary differentiability that allows consideration of the rate of change of one function with respect to another. Fréchet differentiability not only is important in risk theory (Machina, 1982) but has been invoked in the field of dynamic analysis (Lyon and Bosworth, 1991) to argue for a reassessment of some of the received dynamic theory (Treadway, 1970) cited by agricultural economists in interpreting empirical results (Vasavada and Chambers, 1986; Howard and Shumway, 1988).

- **The modeling of information.** The information available to individuals plays a pivotal role in their economic behavior. Thus, in analyzing such subjects as food safety, crop insurance, and the purchase of commodities of uncertain quality, economists must somehow incorporate this intangible entity, information, into their models. We will describe two approaches to dealing with this problem. First, we will introduce the notion of a Borel field of sets. This seemingly abstruse tool is now fundamental to finance theory, where increasing families of Borel fields are used to represent the flow of information available to a trader over time. Second, we will discuss how the choice set of an economic agent's risk preference ordering can be used to distinguish between situations of certainty and uncertainty.

- **The measurement of individuals' risk attitudes.** A question of both theoretical and empirical interest in the risk literature, one whose answer is important for the practical elicitation of risk preferences, is whether individuals' utility functions for risky choices are (a) determined by, or (b) essentially separate from, their utility functions for riskless choices. It has been widely assumed that case (a) prevails within expected utility theory. We will show, however, that within this theory, the utility function for continuous probability distributions can be constructed independently of the utility function for riskless choices. Thus, expected utility theory permits more flexible functional forms than perhaps generally realized. If an individual uses distinct rules for choosing among certainties and among continuous probability distributions, the expected utility paradigm may still be applicable.

Mathematical Preliminaries

The starting point for a clear understanding of risk is a clear understanding of the basic mathematical objects (random variables, probability spaces, and so forth) in terms of which risk is discussed and modeled. Since much of contemporary risk theory is described in the language of set theory, we first review some basic terminology from that subject.

The notation "$s \in S$" indicates that s is an element of the set S, while the brace notation "$\{2,5,3\}$" defines $\{2,5,3\}$ as a set whose elements are 2, 5, and 3. Two sets are equal if and only if they contain the same elements. Thus, $\{5,2,3,3\}$ is equal to $\{2,5,3\}$; the order of listing is immaterial as is the appearance of an element more than once. The set of all x such that x satisfies a property P is denoted $\{x \mid P(x)\}$. Thus, within the realm of real numbers, $\{x \mid x^2 = 1\}$ is the set $\{-1,1\}$. There is a unique set, called the *empty* set and denoted $\varnothing$, that contains no elements.

For any sets A_1 and A_2, their *intersection*, $A_1 \cap A_2$, is the set $\{x \mid \text{for each } i,\ x \in A_i\}$, their *union*, $A_1 \cup A_2$, is $\{x \mid \text{for at least one } i,\ x \in A_i\}$, and their *difference*, $A_1 \setminus A_2$, is $\{x \mid x \in A_1 \text{ and not } x \in A_2\}$. The definitions of union and intersection extend straightforwardly to any finite or infinite collection of sets. A set A_1 is a *subset* of a set A_2 if each element of A_1 is an element of A_2.

A set of the form $\{\{a\},\{a,b\}\}$ is called an *ordered pair* and denoted (a,b). The essential feature of ordered pairs, that (a,b) = (c,d) if and only if a = c and b = d, is easily demonstrated. If A and B are sets, their *Cartesian product*, $A \times B$, is the set of all ordered pairs (a,b) for which $a \in A$ and $b \in B$. The extension to ordered n-tuples $(a_1,\ldots,a_n)$ and n-fold Cartesian products $A_1 \times \ldots \times A_n$ is straightforward.

A *relation* is a set of ordered pairs. If R is a relation, the set $\{x \mid \text{for some } y\ (x,y) \in R\}$ is called the *domain* of R (denoted D_R), and the set $\{y \mid \text{for}$

some x $(x,y) \in R\}$ is called the *range* of R (denoted R_R). A *function* (or *mapping*) is a relation for which no two distinct ordered pairs have the same first coordinate. When f is a function and $(x,y) \in f$, y is denoted f(x) and called the *value* of f at x. Symbolism like $f: A \to B$ (read "f maps A into B") indicates that f is a function whose domain is A and whose range is a subset of B.

Finally, if c is a number and f,g are real-valued functions having a common domain D, then cf and f + g are functions defined on D by $[cf](x) = cf(x)$ and $[f+g](x) = f(x) + g(x)$ for each $x \in D$. If f and g are *any* functions, then $f \circ g$, the *composition* of f and g (in that order), is the function defined by $[f\circ g](x) = f\big(g(x)\big)$ for each x in the domain $D_{f\circ g} \equiv \{x \mid x \in D_g \text{ and } g(x) \in D_f\}$.

Representations of Risk

As Stokey and Lucas (1989) point out, measure theory, which has served as the mathematical foundation of the theory of probability since the 1930's, is rapidly becoming the standard language of the economics of uncertainty. We sketch a few of the basic ideas of this subject.

Borel Fields of Events

In probability theory, the events to which probabilities are assigned are represented as subsets of a sample space of possible outcomes. Thus, in the toss of a standard, six-sided die, the event "an even number comes up" would be represented as the subset {2,4,6} of the sample space {1,2,3,4,5,6}. However, it is not logically possible, in general, to assign a probability to every subset of a sample space. To see why, imagine an ideal mathematical dart thrown randomly, according to a uniform probability distribution, into the interval [0,1]. The probability of hitting the subinterval [3/5,4/5] would be 1/5. Likewise, the probability of hitting any other subset of [0,1] would seem to be its length. But, there are subsets of [0,1], called nonmeasurable, that *have* no length. To construct an example, define any two numbers in [0,1] as "equivalent" if their difference is rational. This equivalence relation partitions [0,1] into a union of disjoint equivalence sets analogous to the indifference sets of demand theory. Choose one number from each equivalence set. Then, the set of these choices is nonmeasurable (see Natanson, 1955, pp. 76-78.)

Thus, some subsets cannot be assigned a probability in the situation we have described. One cannot assume, therefore, that every subset of an arbitrary sample space can be assigned a probability. Rather, in every risk model, the question of which subsets of the sample space are admissible must be addressed individually.

A set of admissible subsets of a sample space is characterized axiomatically as follows. Let Ω be a set (interpreted as a sample space) and F a collection (that is, a set) of subsets of Ω such that (1) $\Omega \in F$, (2) $\Omega\backslash A \in F$ whenever $A \in F$, and (3) $\bigcup_{i=1}^{\infty} A_i \in F$ whenever $\{A_i\}_{i=1}^{\infty}$ is a sequence of elements of F. Then, F is called a *Borel field*. F plays the role of a collection of events to which probabilities can be assigned. By ensuring that F is closed under various set-theoretic operations on the events in it, conditions 1-3 guarantee that certain natural logical combinations of events in F will also be in F. For example, application of 1-3 to the set-theoretic identity $A\cap B = \Omega\backslash[(\Omega\backslash A)\cup(\Omega\backslash B)]$ implies that $A\cap B$, the event whose occurrence amounts to the joint occurrence of A and B, is in F whenever A and B are.

Borel fields have an interpretation as "information structures" in the following sense. For simplicity, let the sample space Ω be the interval [0,1], let F be the smallest Borel field over Ω that includes among its elements the intervals [0,1/2) and [1/2,1] (so that $F = \{\varnothing, [0,1/2), [1/2,1], [0,1]\}$), and let F' be the smallest Borel field over Ω that includes among its elements the intervals [0,1/4), [1/4,1/2), and [1/2,1] (so that $F' = \{\varnothing, [0,1/4), [1/4,1/2), [1/2,1], [0,1/2), [1/4,1], [0,1/4)\cup[1/2,1], [0,1]\}$). Suppose an outcome ω_0 in Ω is realized, but all that is to be revealed to us is the identity of an event in F that has thereby occurred (that is, the identity of an event $E \in F$ for which $\omega_0 \in E$). Then, the most that we could potentially learn about the location of ω_0 in Ω would be either that ω_0 lies in [0,1/2) or that ω_0 lies in [1/2,1]. However, if we were instead to be told the identity of an event in F' that has occurred, we would have the possibility of learning certain additional facts about ω_0 not available through F. For example, we might learn that the event [0,1/4) in F' has occurred, so that $\omega_0 \in [0,1/4)$.

Observe that, in this example, F' contains every event in F and additional events not in F. That is, F is a strict subset of F'. Thus, F' offers a richer supply of events to help us home in on the realized state of the world, ω_0. In this sense, whenever any Borel field is a subset of another, the second may be interpreted to be at least as informative as (and, in the case of strict inclusion, more informative than) the first.

A particularly important Borel field over the real line $\mathbb{R}$ is denoted B and defined as follows. First,

note that the set of all subsets of $\mathbb{R}$ is a Borel field that contains all intervals as elements. Second, observe that the intersection of any number of Borel fields over the same set is itself a Borel field over that set. Define B as the intersection of *all* Borel fields over $\mathbb{R}$ that contain all intervals as elements. Then, B is itself a Borel field over $\mathbb{R}$ containing all intervals as elements. Moreover, it is the "smallest" such Borel field, since it is a subset of each such Borel field. The elements of B are known as *Borel sets*.

Probability Measures and Probability Spaces

Let P be a nonnegative real-valued function whose domain is a Borel field F over a set Ω. Then, P is called a *probability measure* on Ω and Ω (or, alternatively, the triple (Ω,F,P) is called a *probability space* if (1′) $P(\Omega) = 1$ and (2′) $P(\bigcup_{i=1}^{\infty} A_i) = \sum_{i=1}^{\infty} P(A_i)$ whenever $\{A_i\}_{i=1}^{\infty}$ is a sequence of elements of F that are pairwise disjoint (that is, for which $i \neq j$ implies $A_i \cap A_j = \varnothing$). Condition 2′ asserts that the probability of the occurrence of exactly one event out of a sequence of pairwise incompatible events is the sum of the individual probabilities. Probability measures on $\mathbb{R}$ having domain B are called *Borel* probability measures.

Random Variables

Finally, suppose (Ω,F,P) is a probability space and r a real-valued function with domain Ω. Then, r is called a *random variable* if, for every Borel set B in $\mathbb{R}$, $\{\omega \mid \omega \in \Omega \text{ and } r(\omega) \in B\} \in F$. (A function r satisfying this condition is said to be *measurable* with respect to F.) The effect of the measurability condition is to ensure that a situation like "random crop yield will lie in the interval I" corresponds to an element of F and can thus be assigned a probability by P.

A random variable measurable with respect to a Borel field F can be interpreted as depending only on the information inherent in F. For example, in finance theory, the flow of information over a time interval $[0,T]$ is represented by a family of Borel fields F_t $(0 \leq t \leq T)$ satisfying (among other conditions) the requirement that F_s be a subset of F_t whenever $s \leq t$ (information is nondecreasing over time). Correspondingly, the moment-to-moment price of a commodity is represented by a family of random variables p_t $(0 \leq t \leq T)$ such that, for each t, p_t is measurable with respect to F_t. In this manner, the price at time t is portrayed as depending only on the information available in the market at that time. (For additional details, see Dothan, 1990). Similarly, in stochastic dynamic policy models, a decisionmaker's contingent decisions over time are represented by a family of random variables r_t related to an increasing family of Borel fields F_t by the requirement that each r_t be measurable with respect to F_t.

Notwithstanding its name, a random variable is not random, and it is not a variable. It is a function, a set of ordered pairs of a certain type. Randomness or variability are aspects not of random variables themselves but, rather, of the *interpretations* we imagine when we use random variables to model real phenomena. For example, when we model a farmer's crop yield, we use a random variable (hence, a function), r, to represent *ex ante* yield, but we use a function *value*, $r(\omega)$, to represent *ex post* yield. What determines ω? We interpret nature as having "randomly" selected ω from the probability space on which r is defined.

Agricultural economists often represent stochastic production through forms such as $f(x) + \varepsilon$, where $x \in \mathbb{R}^n$ is interpreted as a vector of inputs and ε is interpreted as a random disturbance. Despite superficial appearances, such a construct is not a sum of a production function and a random variable. Rather, it is a *random field* (Ivanov and Leonenko, p. 5). To characterize it in precise terms, suppose f is a (production) function and ε a random variable. Define a function Φ having domain $D_\varepsilon \times D_f$ by $\Phi((\omega,x)) = f(x) + \varepsilon(\omega)$ for each $\omega \in D_\varepsilon$ and each $x \in D_f$. Then, Φ is a formal representation of stochastic production with additive error, and various functions defined in terms of Φ represent specific aspects of stochastic production. For example, for each $x \in D_f$, the random variable $\Phi(\cdot,x)$ defined on D_ε by $[\Phi(\cdot,x)](\omega) = \Phi((\omega,x))$ represents *ex ante* production under the input x. Similarly, for each $\omega \in D_\varepsilon$, the function $\Phi(\omega,\cdot)$ defined on D_f by $[\Phi(\omega,\cdot)](x) = \Phi((\omega,x))$ represents the effect of input choice on *ex post* production (that is, on the particular *ex post* production associated with nature's random "selection" of ω).

Another example of a random field is provided by the idea of signaling in principal-agent theory (Spremann, 1987, p. 26). Suppose the effort expended by an economic agent (for instance, the effort expended by a producer to ensure the safety of food) is unobservable by the principal (here, the consumer), but some "noisy function of" the effort *can* be observed. Such a signal of hidden effort may be defined formally as follows. Let h be the (real-valued) observer function (its domain is the set of allowable effort levels) and let ε be a random variable. Then, the function $z\colon D_h \times D_\varepsilon \to \mathbb{R}$ defined for each $e \in D_h$, $\omega \in D_\varepsilon$ by $z(e,\omega) = h(e) + \varepsilon(\omega)$ is a

random field that serves as a monitoring signal of effort.

When a risk situation can be represented by a random variable, it can equally well be represented by infinitely many distinct random variables. (For example, there exist infinitely many distinct normal random variables having mean 0 and variance 1, each defined on a different probability space.) For this reason, random variables cannot model situations of risk uniquely. However, to every random variable r defined on a probability space (Ω,F,P), there corresponds a unique Borel measure, P_r, on $\mathbb{R}$ satisfying $P_r(B) = P(\{\omega \mid \omega \in \Omega \text{ and } r(\omega) \in B\})$ for each Borel set B. (P_r is called the *probability distribution* of r.) In addition, there corresponds a unique function F_r: $\mathbb{R} \to [0,1]$, the *cumulative distribution function* (*c.d.f.*) of r, such that $F_r(t) = P(\{\omega \mid \omega \in \Omega \text{ and } r(\omega) \leq t\})$ for each $t \in \mathbb{R}$. P_r and F_r contain the same probabilistic information as r, but in a form more convenient for certain computational purposes.

The c.d.f. of a random variable r is always (1) nondecreasing and (2) continuous on the right at each point of $\mathbb{R}$. In addition, (3) $\lim_{t \to -\infty} F_r(t) = 0$ and $\lim_{t \to \infty} F_r(t) = 1$. Conversely, any function F: $\mathbb{R} \to [0,1]$ enjoying properties 1-3 can be shown to be the c.d.f. of some random variable. Thus, we are free to view the set of all c.d.f.'s as simply the set of all functions F: $\mathbb{R} \to [0,1]$ satisfying 1-3.

Random Functions

Random variables, Borel measures, and c.d.f.'s are tools for representing the chance occurrence of scalars. They can be generalized to n-dimensional random vectors, probability measures on $\mathbb{R}^n$, and n-dimensional c.d.f.'s to represent the chance occurrence of vectors in $\mathbb{R}^n$. However, even more general tools are sometimes needed for the conceptualization of risk in agriculture. For example, the yield of a corn plant depends on, among other things, the surrounding temperature over the period of growth. It is reasonable to express this temperature as a real-valued function, τ, defined on some time interval, [0,t]. Yet τ, as a constituent of weather, must be regarded as determined by chance. Thus, the probability distribution of the plant's yield depends on the probability distribution by which nature "selects" the temperature function. Just as the probability distribution of a random variable is a probability measure defined on a set of numbers, this notion of the probability distribution of a random function finds its natural expression in the form of a probability measure defined on a probability space of functions.

Similarly, consider stochastic crop production, CP_L, over a region, L, in the plane $\mathbb{R}^2$. Since yield, like weather, can vary over a region, it is appropriate to define CP_L not merely as the traditional "acreage times yield" but, rather, as the integral over L of a yield (or production density) function defined at each point of L. That is, suppose Ω is a probability space representing weather outcomes, X a set of input vectors, and Y: $\Omega \times X \times L \to \mathbb{R}_+$ a stochastic pointwise yield function such that, for each choice $x \in X$ of inputs and each location $\lambda \in L$, the function $Y(\cdot, x, \lambda)$: $\Omega \to \mathbb{R}_+$ (interpreted as the *ex ante* yield at the location λ given input choice x) is a random variable.[2] Then, for each weather outcome $\omega \in \Omega$, the corresponding *ex post* crop production over L given input vector x can be expressed as $CP_L(\omega,x) = \int_L Y(\omega,x,\lambda)d\lambda$ whenever the integral exists. However, the integrand (the *ex post* pointwise yield function $Y(\omega,x,\cdot)$: $L \to \mathbb{R}_+$) is determined by chance, since it is parameterized by ω. Thus, the probability distribution (if it exists) of $CP_L(\cdot,x)$, that is, of *ex ante* production over L given x, depends on the probability distribution by which nature selects the integrand. The latter notion is, again, expressed naturally by a probability measure defined on a probability space of functions, in this case functions mapping the region L into $\mathbb{R}$.

Individual Choice Under Risk

Like the theory of consumer demand, the theory of choice under risk begins with an ordering that expresses an individual's preferences among the elements of a designated set. In demand theory, that set consists of vectors representing commodity bundles. In risk theory, it consists of mathematical constructs (random variables, c.d.f.'s, probability measures, or the like) capable of representing situations of risk.

Preference Orderings

Suppose $\succcurlyeq$ is a relation such that $D_{\succcurlyeq} = R_{\succcurlyeq}$ (in which case $\succcurlyeq$ is a subset of $D_{\succcurlyeq} \times D_{\succcurlyeq}$ and relates elements of $D_{\succcurlyeq}$ to elements of $D_{\succcurlyeq}$). Write $a \succcurlyeq b$ to signify that $(a,b) \in \succcurlyeq$. Then, $\succcurlyeq$ is called a *preference ordering* if it is complete (that is, $a \succcurlyeq b$ or $b \succcurlyeq a$ for any elements a,b of $D_{\succcurlyeq}$) and transitive (that is, for any elements a,b,c of $D_{\succcurlyeq}$, $a \succcurlyeq c$ whenever $a \succcurlyeq b$ and $b \succcurlyeq c$). When $\succcurlyeq$ is a preference ordering, the assertion $a \succcurlyeq b$ is read "a is weakly preferred to b" and interpreted to mean that the economic agent either prefers a to b or is indifferent between a and b.

[2]Y constitutes our third example of a random field.

Though individuals' preferences are often considered empirically unobservable, there is nothing indefinite about the *concept* of a preference ordering. In contemporary economic theory, preference orderings are mathematical objects, and they can be examined, manipulated, and compared as such. For example, $\geqslant$, the ordinary numerical relation "greater than or equal to," is a preference ordering of $\mathbb{R}$. Formally, as a set of ordered pairs, it is simply the closed half-space lying below the line $y = x$ in the plane $\mathbb{R} \times \mathbb{R} = \mathbb{R}^2$. Thus, it can be compared as a geometric object to other subsets of $\mathbb{R}^2$ that signify preference orderings of $\mathbb{R}$. This geometric perspective can be invoked in investigating whether two preference orderings are the same, whether they are near one another, and so forth. Similarly, preference orderings of other sets S, including sets of c.d.f.'s or other representations of risk, can be studied as geometric objects in $S \times S$. In this context is to be found the formal meaning (if not the econometric resolution) of such empirical questions as "have consumer preferences for red meat changed?" or "are poor farmers more risk averse than wealthy farmers?"

Lotteries and Convexity

What properties are appropriate to require of a set of risk representations before a preference ordering of it can be defined? Expected utility theory imposes only one restriction: the set of risk representations must be closed under the formation of compound lotteries.

A "lottery" may be viewed as a game of chance in which prizes are awarded according to a preassigned probability law. Suppose a lottery L offers prizes L_1 and L_2 having respective probabilities p and $1 - p$ of occurring. If L_1 and L_2 are themselves lotteries, L is called a *compound* lottery.

Consider a farmer whose crops face an insect infestation having probability p of occurring. Assume weather to be random. Then, the farmer would receive one income distribution with probability p, another with probability $1 - p$. This situation has the form of a compound lottery.

What expected utility theory requires of the domain of a preference ordering is that whenever two lotteries with monetary prizes lie in the domain, any compound lottery formed from them must lie in it as well. Now, mathematically, lotteries L_1, L_2 with numerical prizes can be represented by c.d.f.'s C_1, C_2. If the internal structure of a compound lottery is ignored and only the distribution of the lottery's final numerical prizes is considered, then the compound lottery L offering L_1 and L_2 as prizes with probabilities p and $1 - p$ is represented by the c.d.f. $pC_1 + (1-p)C_2$. Thus, the requirement that the domain of a preference ordering be closed under compounding is expressed formally by the requirement that, whenever c.d.f.'s C_1, C_2 lie in the domain, any convex combination $pC_1 + (1-p)C_2$ of them must lie in it as well. However, within the vector space over $\mathbb{R}$ of all functions mapping $\mathbb{R}$ into $\mathbb{R}$ (Hoffman and Kunze, 1961, pp. 28-30), $pC_1 + (1-p)C_2$ is nothing but a point on the line segment joining C_1 and C_2. Thus, this entire line segment is required to lie in the domain whenever its endpoints do. In short, the domain is required to be convex (Kreyszig, 1978, p. 65).

The ability of c.d.f.'s to represent compound lotteries as convex combinations is shared by Borel probability measures but not by random variables. Thus, expected utility theory and the related risk literature usually deal with c.d.f.'s or probability measures rather than random variables. Formally, the term *lottery* is commonly used to denote either a c.d.f. or a probability measure, depending on context. For this article, we define a lottery to be a c.d.f. A *lottery space* is a convex set of lotteries. By a *risk preference ordering*, we mean a preference ordering whose domain is a lottery space.

Keep in mind that not all situations of individual choice in the presence of risk are appropriately modeled by the simple optimization of a risk preference ordering. Risk preference orderings are intended to compare risks and risks only. By contrast, a consumer's decision whether to obtain protein through consumption of peanut butter (a potential source of aflatoxin) or chicken (a potential source of salmonella) involves questions of taste as well as risk. Unless these influences can be separated, standard risk theories—expected utility or otherwise—will not apply.

Choice Sets and the Modeling of Information

As a result of budget constraints or other restrictions dictated by particular circumstances, an individual's choices under risk will generally be confined to a strict subset of the lottery space $D_{\geqslant}$ termed the choice set. It is this set on which are ultimately imposed a model's assumptions concerning what is known versus unknown, certain versus uncertain to the economic agent.

Several areas of concern to agricultural economists—food safety, nutrition labeling, grades and standards, and product advertising—are intimately tied to the economics of information (and, by extension, to the economics of uncertainty). The inability of consumers to detect many food contami-

nants unaided, for example, limits producers' economic incentives to compete on the basis of food safety. Government policy aims both to reduce risks to consumers and to provide information about what risks do exist. How, though, can assumptions about, or changes in, a consumer's information or uncertainty be incorporated explicitly into a mathematical model? The agent's choice set would often appear to be the proper vehicle for representing these factors. For example, when the agent is assumed to be choosing under certainty, the choice set is confined to constructs representing certainties, such as c.d.f.'s of constant random variables. When the agent is assumed to be choosing under risk, representations of certainty are *excluded* from the choice set, and only those lotteries are allowed that conform to the economic and probabilistic assumptions of the model. The choice set of lotteries in a model of behavior under risk plays no less important a role than the set of feasible, budget-constrained commodity bundles in a model of consumer demand. In each case, the optimum achieved by the economic agent is crucially dependent on the set over which preferences are permitted to be optimized.

Utility Functions on Lottery Spaces

Let $\geqslant$ be a risk preference ordering. A function U: $D_{\geqslant} \to \mathbb{R}$ is called a *utility function* for $\geqslant$ if, for any elements a,b of $D_{\geqslant}$, $U(a) \geqslant U(b)$ if and only if $a \geqslant b$. A function U: $D_{\geqslant} \to \mathbb{R}$ is called *linear* if $U\big(tL_1 + (1-t)L_2\big) = tU(L_1) + (1-t)U(L_2)$ whenever $L_1, L_2 \in D_{\geqslant}$ and $0 \leqslant t \leqslant 1$.

Linearity in the above sense must be distinguished from the notion of linearity customarily applied to mappings defined on vector spaces (Hoffman and Kunze, 1961, p. 62). Indeed, a lottery space cannot be a vector space since, for example, the sum of two c.d.f.'s is not a c.d.f. Rather, the assumption that a function U: $D_{\geqslant} \to \mathbb{R}$ is linear in our sense is analogous to the assumption that a function g: $\mathbb{R} \to \mathbb{R}$ has a straight-line graph, that is, that g is both concave ($g(\lambda x + (1-\lambda)y) \geqslant \lambda g(x) + (1-\lambda)g(y)$ whenever $x, y \in D_g$ and $0 \leqslant \lambda \leqslant 1$) and convex ($g(\lambda x + (1-\lambda)y) \leqslant \lambda g(x) + (1-\lambda)g(y)$ whenever $x, y \in D_g$ and $0 \leqslant \lambda \leqslant 1$), or, equivalently, that $g(\lambda x + (1-\lambda)y) = \lambda g(x) + (1-\lambda)g(y)$ whenever $x, y \in D_g$ and $0 \leqslant \lambda \leqslant 1$.[3] Restated for a function U: $D_{\geqslant} \to \mathbb{R}$, the latter condition expresses precisely the concept of linearity introduced above.

An assumption of linearity requires, in effect, that a compound lottery be assigned a utility equal to the expected value of the utilities of its lottery prizes. Though stated for a convex combination of two lotteries, the formula in the definition of linearity is easily shown to extend to a convex combination of n lotteries. For example, we can use the convexity of $D_{\geqslant}$ to express $p_1L_1 + p_2L_2 + p_3L_3$, a convex combination of three elements of $D_{\geqslant}$, as a convex combination of *two* elements of $D_{\geqslant}$, obtaining (under the conventions $p_2 + p_3 \neq 0$, $p_2' \equiv p_2/(p_2+p_3)$, $p_3' \equiv p_3/(p_2+p_3)$):

$$
\begin{aligned}
U(p_1L_1 + p_2L_2 + p_3L_3) \\
&= U\big(p_1L_1 + (p_2+p_3)(p_2'L_2 + p_3'L_3)\big) \\
&= p_1U(L_1) + (p_2+p_3)U(p_2'L_2 + p_3'L_3) \\
&= p_1U(L_1) + (p_2+p_3)p_2'U(L_2) + (p_2+p_3)p_3'U(L_3) \\
&= p_1U(L_1) + p_2U(L_2) + p_3U(L_3).
\end{aligned}
$$

A similar argument applied recursively to a convex combination of n elements of $D_{\geqslant}$ can be used to establish the general case.

Utility functions allow questions about risk preference orderings to be recast into equivalent questions about real-valued functions defined on lottery spaces. The benefit of this translation is most apparent when the utility function can itself be expressed in terms of another "utility function" that maps not lotteries to numbers but *numbers* to numbers, for then the techniques of calculus can be applied. It is on utility functions of the latter type that the attention of agricultural economists is usually focused.

Although such wholly numerical utility functions are frequently described as "von Neumann-Morgenstern" utility functions, von Neumann and Morgenstern (1947) were concerned with assigning utilities to lotteries, not numbers. Using a very general concept of lottery, they demonstrated that any risk preference ordering satisfying certain plausible behavioral assumptions can be represented by a linear utility function. They did not prove, nor does it follow from their assumptions, that a linear utility function, U, must give rise to a numerical function u such that the utility of an arbitrary lottery L has an expected utility integral representation of the form $U(L) = \int_{-\infty}^{\infty} u(t)dL(t)$.

Conditions guaranteeing that a linear utility function has an integral representation of this type were given by Grandmont (1972). However, one of these conditions fails to hold for the lottery space of all c.d.f.'s having finite mean, which is a natural lottery space on which to consider risk aversion.

Numerical Utility Functions

What is the general relationship between numerical utility functions and the more fundamental utility

[3]Such a function g is linear as a vector space mapping if and only if g(0) = 0.

functions defined on lottery spaces? To examine this question, we introduce the following definitions.

For each $r \in \mathbb{R}$, the lottery δ_r defined by:

$$\delta_r(t) = \begin{cases} 0 \text{ if } t \leq r \\ 1 \text{ if } t > r \end{cases}$$

is called *degenerate*. δ_r is the c.d.f. of a constant random variable with value r. Thus, it represents "r with certainty."

Suppose U is a utility function for a risk preference ordering $\succcurlyeq$ whose domain, $D_{\succcurlyeq}$, contains all degenerate lotteries. Define a function $u: \mathbb{R} \to \mathbb{R}$ by:

$$u(r) = U(\delta_r),$$

for each $r \in \mathbb{R}$. We call u the *utility function induced on* $\mathbb{R}$ *by* U. u is a numerical function that, importantly, encapsulates the action of U under certainty.

A lottery L is called *simple* if it is a convex combination of a finite number of degenerate lotteries, that is, if there exist degenerate lotteries $\delta_{r_1}, \ldots, \delta_{r_n}$ and nonnegative numbers $p_1, \ldots, p_n$ such that $\sum_{i=1}^{n} p_i = 1$ and $L = \sum_{i=1}^{n} p_i\delta_{r_i}$. In this case, L is the c.d.f. of a random variable taking the value r_i with probability p_i ($i = 1, \ldots, n$).

Now, let U be a linear utility function whose domain contains all degenerate lotteries. Then u, the utility function induced on $\mathbb{R}$ by U, is defined. Moreover, by the convexity property of a lottery space, the domain of U contains all simple lotteries. Consider any simple lottery $L \equiv \sum_{i=1}^{n} p_i\delta_{r_i}$, and let X be a random variable whose c.d.f. is L. Then, the composite function $u \circ X$ is a random variable taking the value $u(r_i)$ with probability p_i ($i = 1, \ldots, n$), and it follows that:

$$U(L) = \sum_{i=1}^{n} p_i U(\delta_{r_i})$$

$$= \sum_{i=1}^{n} p_i u(r_i)$$

$$= E(u \circ X),$$

that is, U(L) is the expected value of $u \circ X$.[4] However, unless additional restrictions (such as those of Grandmont (1972)) are imposed, U(L) cannot, in general, be expressed as the expectation of the induced utility function when L is *not* simple. In fact, a significant part of U is *independent* of its induced utility function and therefore independent of U's utility assignments under certainty. We turn next to this subject—the structural distinctness within a linear utility function of its "certainty part" and a portion of its "uncertainty part" (Weiss, 1987, 1992).

[4]In the applied literature, $u \circ X$ is often incorrectly identified with u. $u \circ X$ is a random variable, while u is not.

Decomposition of Linear Utility Functions

A linear utility function can be decomposed into a "continuous part" and a "discrete part." The latter encodes all aspects of U relating to behavior under certainty. Unless additional restrictions are imposed, the former is entirely independent of behavior under certainty.

To describe this decomposition satisfactorily, we require the following definitions. A lottery is called *continuous* if it is continuous as an ordinary function on $\mathbb{R}$. A lottery L is called *discrete* if it is a convex combination of a sequence of degenerate lotteries, that is, if there exist a sequence $\{\delta_{r_i}\}_{i=1}^{\infty}$ of degenerate lotteries and a sequence $\{p_i\}_{i=1}^{\infty}$ of nonnegative numbers such that $\sum_{i=1}^{\infty} p_i = 1$ and $L = \sum_{i=1}^{\infty} p_i\delta_{r_i}$. Such a lottery L is the c.d.f. of a random variable taking the value r_i with probability p_i ($i = 1, 2, 3, \ldots$). Every simple lottery (and thus every degenerate lottery) is discrete.

Now, every lottery L has a decomposition:

$$L = p_L L_c + (1-p_L)L_d,$$

such that $0 \leq p_L \leq 1$, L_c is a continuous lottery, and L_d is a discrete lottery (Chung, 1974, p. 9). (Such decompositions occur naturally in the economics of risk, as when an agricultural price support or other insurance mechanism truncates a random variable whose c.d.f. is continuous, leading to a "piling up" of probability mass at one point. See Weiss, 1987, pp. 69-70, or Weiss, 1988.) Moreover, p_L is unique, L_c is unique if $p_L \neq 0$, and L_d is unique if $p_L \neq 1$. It follows that if U is a linear utility function whose domain contains L, L_c, and L_d, then $U(L) = p_L U(L_c) + (1-p_L)U(L_d)$. Thus, U is entirely determined by its action on continuous lotteries and its action on discrete lotteries. If, moreover, the domain of U contains all degenerate lotteries and U is countably linear over such lotteries in the sense that $U(L) = \sum_{i=1}^{\infty} p_i U(\delta_{r_i})$ for any discrete lottery $L = \sum_{i=1}^{\infty} p_i\delta_{r_i}$ in its domain, then U

is entirely determined by its action on continuous lotteries and its action at certainties.

The foregoing remarks show how function values of U can be decomposed, but they do not indicate how U itself, as a function, can be decomposed. A full description of this functional decomposition cannot be given here. In brief, however, one uses the rule $U^*(pL) \equiv pU(L)$ to extend U to a new function, U^*, defined on an enlarged domain consisting of all product functions pL for which $0 \leqslant p \leqslant 1$ and $L \in D_U$ (such product functions are called *sublotteries*). Then (assuming $L \in D_U$ implies (1) $L_c \in D_U$ if $p_L \neq 0$ and (2) $L_d \in D_U$ if $p_L \neq 1$), U^* has a decomposition:

$$U^* = U^*_c + U^*_d,$$

into unique functions U^*_c and U^*_d that are defined and linear over sublotteries, map the zero sublottery to itself, and depend only on the continuous or discrete part, respectively, of a sublottery (see Weiss, 1987).

We have described how a linear utility function can be resolved into its continuous and discrete parts. Conversely, one can *construct* a linear utility function out of a linear utility function defined over continuous lotteries and a linear utility function defined over discrete lotteries. In fact, if V_1 is a linear function defined over all continuous lotteries and V_2 a bounded real-valued function defined over all degenerate lotteries, a function V can be defined at any lottery:

$$L = p_L L_c + (1-p_L) \sum_{i=1}^{\infty} p_i \delta_{r_i},$$

by the rule:

$$V(L) \equiv p_L V_1(L_c) + (1-p_L) \sum_{i=1}^{\infty} p_i V_2(\delta_{r_i}).$$

V will be a linear utility function for the preference ordering $\geqslant$ defined for all pairs of lotteries by: $L_1 \geqslant L_2$ if and only if $V(L_1) \geqslant V(L_2)$. In this manner, one can construct risk preference orderings for which the utilities assigned to continuous lotteries are independent of those assigned to certainties—in short, risk preference orderings for which, in appropriate choice sets, behavior under risk is independent of, and cannot be predicted from, behavior under certainty.

This construction provides a useful illustration of why the traditional, graphical approach to risk is inadequate: the graph of the utility function induced on $\mathbb{R}$ (by V) provides no information concerning, say, the individual's risk preferences among normal c.d.f.'s. One also sees from this construction that the utility function induced on $\mathbb{R}$ by a linear utility function need not itself be linear (in the sense of having a straight-line graph).

Risk Aversion

Risk aversion is a purely ordinal notion, a property of risk preference orderings. Suppose $\geqslant$ is a risk preference ordering such that each lottery, L, in $D_{\geqslant}$ has a finite mean, E(L), for which $\delta_{E(L)} \in D_{\geqslant}$. Then, $\geqslant$ is called *risk averse* if, for each $L \in D_{\geqslant}$, $\delta_{E(L)} \geqslant L$. That is, an individual is risk averse if a guaranteed payment equal to the expected value of a lottery is always (weakly) preferred to the lottery itself.

Risk aversion is often identified with the concavity of a numerical utility function, and this characterization plays an important role in applied risk studies. The techniques of the preceding paragraphs, however, demonstrate that the equivalence is not universally valid. Since a linear utility function can be constructed using independent selections of its induced utility function and its continuous part, it is easy to construct a risk preference ordering that is not risk averse but is represented by a linear utility function whose induced utility function is strictly concave. In addition, while risk aversion does indeed imply concavity of the induced utility function, it is nevertheless possible to construct a risk-averse preference ordering $\geqslant$, a linear utility function V representing $\geqslant$, and a numerical function v *strictly convex* on [0,1] such that, for any continuous lottery L on [0,1] (that is, for which L(0) = 0 and L(1) = 1), one has:

$$V(L) = \int_0^1 v(t)dL(t).$$

This example seems contrary to "common knowledge" about risk aversion, but its real lesson is that there is more to risk aversion and to other risk concepts than can be captured by the traditional approaches.

A correct description of the relationship between risk aversion and the concavity of numerical utility functions can be given using the concept of continuous preferences (Weiss, 1987, 1990). Let us call a utility function U for a risk preference ordering $\geqslant$ *continuous* if, for any lottery L in $D_{\geqslant}$ and any sequence $\{L_i\}_{i=1}^{\infty}$ of lotteries in $D_{\geqslant}$ converging to L in distribution (that is, for which $\lim_{i\to\infty} L_i(x) = L(x)$ for each point x at which L is continuous), one has $\lim_{i\to\infty} U(L_i) = U(L)$. We call a preference ordering continuous if it can be repre-

sented by a continuous utility function. Now, suppose $\succcurlyeq$ is a risk preference ordering represented by a linear utility function having an induced utility function u. Then, (1) if $\succcurlyeq$ is risk averse, u is concave, while (2) if u is concave *and* $\succcurlyeq$ *is continuous*, then $\succcurlyeq$ is risk averse. For proofs, see Weiss (1987).

Statement 2 shows that the assumption of continuous risk preferences is sufficient to ensure the equivalence between concave numerical utility functions and risk-averse preferences. Note, however, that continuity of $\succcurlyeq$ is not guaranteed by continuity of u. In fact, no assumption concerning u alone can guarantee the continuity of either U or $\succcurlyeq$ (Weiss, 1987). Rather, only through assumptions at a more abstract level, beyond the "visible" or "graphable" part of $\succcurlyeq$ or U embodied in u, can the continuity of risk preferences be assured. Here, again, we see the limitations of traditional approaches as a theoretical foundation for empirical risk analysis.

Beyond Linearity: Machina's "Generalized Expected Utility Theory"

Machina (1982) provided an important generalization of expected utility theory by showing that many of the results of the classical theory extend, in an approximate sense, to nonlinear utility functions. His findings, which have attracted attention among agricultural economists (note, for example, Machina, 1985), exemplify the contribution of modern mathematical concepts to risk theory.

At an intuitive level, Machina's work is grounded in the idea that a function f: $\mathbb{R} \to \mathbb{R}$ differentiable at a point x_0 is locally linear in the sense that the line tangent to the graph of f at $(x_0, f(x_0))$ approximates the graph near this point. That is, if $T_{x_0}: \mathbb{R} \to \mathbb{R}$ is the function whose graph is this tangent line, then T_{x_0} approximates f near x_0.

Machina exploited a simple but powerful idea: a differentiable utility function should also be locally linear. Since linearity of the utility function of a preference ordering is the essence of expected utility theory, such local linearity ought to impart at least local (and possibly global) expected utility-type properties to any smooth risk preference ordering, that is, to any risk preference ordering representable by a differentiable utility function.

What, though, is to be meant by the "differentiability" of a utility function of a preference ordering? After all, such functions are defined not on the real line or even on $\mathbb{R}^n$, but on a space of lotteries, of cumulative distribution functions. An answer is provided by the concept of "Fréchet differentiability" (Luenberger, 1969, p. 172; Nashed, 1966), the natural notion of differentiability for a real-valued function defined on a normed vector space (Kreyszig, 1978, p. 59). To motivate a definition, consider that ordinary differentiability of a function f: $\mathbb{R} \to \mathbb{R}$ at a point x_0 can be characterized by the following condition: there exists a continuous function g: $\mathbb{R} \to \mathbb{R}$, linear in the vector space sense (so that $g_{x_0}(tx+y) = tg_{x_0}(x) + g(y)$ and, in particular, $g_{x_0}(0) = 0$), such that:

$$\lim_{x \to x_0} \frac{f(x) - f(x_0) - g_{x_0}(x-x_0)}{x - x_0} = 0. \tag{1}$$

Indeed, when the stated condition holds, the restrictions on g imply that g must be of the form $g_{x_0}(x) = \alpha_{x_0}\, x$ for some $\alpha_{x_0} \in \mathbb{R}$, and equation (1) thus reduces to:

$$\lim_{x \to x_0} \frac{f(x) - f(x_0)}{x - x_0} = \alpha_{x_0} ,$$

implying the differentiability of f at x_0. Conversely, if f is differentiable at x_0, the above condition is satisfied by the function g_{x_0} defined by $g_{x_0}(x) = f'(x_0)x$.

The limit appearing in equation (1) makes use of division by $x - x_0$, an operation having no counterpart for vectors in a general vector space. However, equation (1) can be expressed in the equivalent form:

$$\lim_{x \to x_0} \frac{f(x) - f(x_0) - g_{x_0}(x-x_0)}{|x - x_0|} = 0. \tag{2}$$

The division by an absolute value introduced in this reformulation (and, more particularly, the absolute value itself) *does* have a vector space counterpart, whose description follows.

A *norm*, $\|\cdot\|$, is a real-valued function defined on a vector space and satisfying the following conditions (stated for arbitrary vectors x, y and an arbitrary scalar $r \in \mathbb{R}$): (1) $\|x\| \geqslant 0$; (2) $\|x\| = 0$ only if x is the zero vector; (3) $\|rx\| = |r|\,\|x\|$; (4) $\|x+y\| \leqslant \|x\| + \|y\|$. A norm is a kind of generalized absolute value for a vector space. Intuitively, $\|x\|$ is the distance between x and the zero vector, while $\|x-y\|$ is the distance between x and y.

Now, let V be a real-valued function defined on a vector space $\mathbf{V}$ equipped with a norm $\|\cdot\|$. (Functions of this type are often called *functionals*.) Then, we say V is *Fréchet differentiable at* $v_0 \in \mathbf{V}$ if there exists a real-valued function Λ_{v_0}, both continuous (in the sense that $\|v-v^*\| \to 0$ implies $|\Lambda_{v_0}(v) - \Lambda_{v_0}(v^*)| \to 0$) and linear (in the vector space sense) on $\mathbf{V}$, such that:

$$\lim_{v \to v_0} \frac{V(v) - V(v_0) - \Lambda_{v_0}(v-v_0)}{\|v - v_0\|} = 0. \tag{3}$$

We say V is *Fréchet differentiable* if it is Fréchet differentiable at v for each $v \in \mathbf{V}$. Observe that equation (3) is a direct parallel to equation (2).

The preceding definition provides a straightforward approach to Fréchet differentiability. However, just as in the definition of differentiability on the real line, slight modifications to the underlying assumptions are needed when V is defined only on a subset of **V**. This limitation on V is typical within expected utility theory, because utility functions for preference orderings are defined only on lottery spaces, and the latter, while *subsets* of a vector space (for example, the vector space of all linear combinations of c.d.f.'s), are not *themselves* vector spaces. We omit the complicating details. The essential point is that Fréchet differentiability at v_0 can be defined as long as (1) V is defined at all vectors near in norm-distance to v_0, and (2) Λ_{v_0} is linear and continuous over small (that is, small-norm) difference vectors of the form $v - v_0$, $v \in D_V$.

A statement of Machina's main result can now be given. Assuming $M > 0$, let L be the lottery space consisting of all c.d.f.'s on the closed interval [0,M] (that is, all c.d.f.'s L for which $L(0) = 0$ and $L(M) = 1$). Let $\|\cdot\|$ be the "L^1 norm" $L^1[0,M]$ (Kreyszig, 1978, p. 62), for which:

$$\|L - L^*\| = \int_0^M |L(t) - L^*(t)|\, dt,$$

whenever $L, L^* \in L$. (Note: the symbol "L^1" is standard and independent of our use of "L" to denote a lottery.) Let V be a Fréchet differentiable function defined on L. (Observe that V is automatically a utility function for the risk preference ordering $\succcurlyeq$ defined on L by: $L \succcurlyeq L^*$ if and only if $V(L) \geq V(L^*)$.) Then, for any $L_0 \in L$, there exists a function $U(\cdot, L_0)$: $[0,M] \to \mathbb{R}$ such that:

$$\lim_{\|L - L_0\| \to 0} \frac{V(L) - V(L_0)}{\int_0^M U(t, L_0) dL(t) - \int_0^M U(t, L_0) dL_0(t)} = 1.$$

Thus, when an individual moves from L_0 to a nearby lottery L, the difference in the V-utility values is nearly equal to the difference in the expected values of $U(\cdot, L_0)$ with respect to L and L_0. In this sense, the individual behaves essentially like an expected utility maximizer with "local utility function" $U(\cdot, L_0)$.

Machina also showed how various local properties (that is, properties of the local utility functions) can be used to derive global properties (that is, properties of the utility function V itself). In so doing, he demonstrated that many of the standard results of expected utility analysis remain valid under weaker assumptions than previously realized.

The applicability of Fréchet differentiation in economics is not limited to risk theory. For example, Lyon and Bosworth (1991) use Fréchet differentiation to investigate the generalized cost of adjustment model of the firm in an infinite dimensional setting. They call into question the acceptance within received theory of a disparity in the slopes of static and dynamic factor demand functions. Their results, if correct, would have implications for agricultural economics studies that have relied on the received theory to interpret their empirical findings (Vasavada and Chambers, 1986; Howard and Shumway, 1988).

Conclusions

The theory of individual choice under risk is a subject in ferment. Spurred on by the contributions of Machina and others, researchers are actively seeking an empirically more realistic paradigm to describe behavior under risk. Their search deserves the attention and participation of agricultural economists.

Today, the frontier of research on behavior under risk employs such mathematical tools as measure theory and functional analysis. Other techniques, including those of differential geometry (Russell, 1991), are on the horizon. What is certain is that the economic analysis of uncertainty is now drawing on technical methods of increased generality and sophistication.

Readers wishing to explore this subject further should benefit from the references already cited. In addition, a more extensive introduction to the contemporary, set-theoretic style of mathematical reasoning used in this article may be found in (Smith, Eggen, and St. Andre, 1986).

References

Chung, Kai Lai. 1974. *A Course in Probability Theory.* 2nd ed. New York: Academic Press.

Dothan, Michael U. 1990. *Prices in Financial Markets.* New York: Oxford University Press.

Duffie, Darrell. 1988. *Security Markets: Stochastic Models.* Boston: Academic Press.

Fishburn, Peter C. 1988. *Nonlinear Preference and Utility Theory.* Baltimore: The Johns Hopkins University Press.

Grandmont, Jean-Michel. 1972. "Continuity Properties of a von Neumann-Morgenstern Utility," *Journal of Economic Theory*. Vol. 4, pp. 45-57.

Hoffman, Kenneth, and Ray Kunze. 1961. *Linear Algebra*. Englewood Cliffs, NJ: Prentice-Hall.

Howard, Wayne H., and C. Richard Shumway. 1988. "Dynamic Adjustment in the U.S. Dairy Industry," *American Journal of Agricultural Economics*. Vol. 70, No. 4, pp. 837-47.

Ivanov, A.V., and N.N. Leonenko. 1989. *Statistical Analysis of Random Fields*. Dordrecht, Holland: Kluwer Academic Publishers.

Kreyszig, Erwin. 1978. *Introductory Functional Analysis With Applications*. New York: John Wiley & Sons.

Luenberger, David G. 1969. *Optimization by Vector Space Methods*. New York: John Wiley & Sons.

Lyon, Kenneth S., and Ken W. Bosworth. 1991. "Dynamic Factor Demand Via the Generalized Envelope Theorem." Manuscript, Utah State University, Logan.

Machina, Mark J. 1982. "'Expected Utility' Analysis Without the Independence Axiom," *Econometrica*. Vol. 50, No. 2, pp. 277-323.

__________. 1983. *The Economic Theory of Individual Behavior Toward Risk: Theory, Evidence and New Directions*. Tech. Rpt. No. 433. Institute for Mathematical Studies in the Social Sciences, Stanford University, Stanford, CA.

__________. 1985. "New Theoretical Developments: Alternatives to EU Maximization." Address to the annual meeting of Southern Regional Research Project S-180 (*An Economic Analysis of Risk Management Strategies for Agricultural Production Firms*), Charleston, SC, March 25, 1985.

__________. 1987. "Choice Under Uncertainty: Problems Solved and Unsolved," *Journal of Economic Perspectives*. Vol. 1, No. 1, pp. 121-54.

Nashed, M.Z. 1966. "Some Remarks on Variations and Differentials," *American Mathematical Monthly*. Vol. 73, No. 4, pp. 63-76.

Natanson, I.P. 1955. *Theory of Functions of a Real Variable*. New York: Frederick Ungar.

Newbery, David M.G., and Joseph E. Stiglitz. 1981. *The Theory of Commodity Price Stabilization*. New York: Oxford University Press.

Russell, Thomas. 1991. "Geometric Models of Decision Making Under Uncertainty," *Progress in Decision, Utility and Risk Theory*. A. Chikán (ed.). Dordrecht, Holland: Kluwer Academic Publishers.

Schoemaker, Paul J.H. 1982. "The Expected Utility Model: Its Variants, Purposes, Evidence and Limitations," *Journal of Economic Literature*. Vol. 20, pp. 529-63.

Smith, Douglas, Maurice Eggen, and Richard St. Andre. 1986. *A Transition to Advanced Mathematics*. 2nd ed. Monterey, CA: Brooks/Cole Publishing Co.

Spremann, Klaus. 1987. "Agency Theory and Risk Sharing," *Agency Theory, Information, and Incentives*. G. Bamberg and K. Spremann (eds.). Berlin: Springer-Verlag.

Stokey, Nancy L., and Robert E. Lucas, Jr., with Edward C. Prescott. 1989. *Recursive Methods in Economic Dynamics*. Cambridge, MA: Harvard University Press.

Treadway, Arthur B. 1970. "Adjustment Costs and Variable Inputs in the Theory of the Competitive Firm," *Journal of Economic Theory*. Vol. 2, No. 4, pp. 329-47.

Vasavada, Utpal, and Robert G. Chambers. 1986. "Investment in U.S. Agriculture," *American Journal of Agricultural Economics*. Vol. 68, No. 4, pp. 950-60.

von Neumann, John, and Oskar Morgenstern. 1947. *Theory of Games and Economic Behavior*. 2nd ed. Princeton, NJ: Princeton University Press.

Weiss, Michael D. 1987. *Conceptual Foundations of Risk Theory*. Tech. Bull. No. 1731. U.S. Dept. Agr., Econ. Res. Serv.

__________. 1988. "Expected Utility Theory Without Continuous Preferences," *Risk, Decision and Rationality*. B.R. Munier (ed.). Dordrecht, Holland: D. Reidel Publishing Co.

__________. 1990. "Risk Aversion in Agricultural Policy Analysis: A Closer Look at Meaning, Modeling, and Measurement," *New Risks: Issues and Management. Advances in Risk Analysis, Vol. 6*. L.A. Cox, Jr. (ed.). New York: Plenum Press.

__________. 1991. "Beyond Risk Analysis: Aspects of the Theory of Individual Choice Under Risk," *Risk Analysis: Prospects and Opportunities. Advances in Risk Analysis, Vol. 8*. C. Zervos (ed.). New York: Plenum Press.

A Simultaneous Econometric Model of World Fresh Vegetable Trade, 1962-82: An Application of Nonlinear Simultaneous Equations

Amy L. Sparks and Ronald W. Ward

Abstract. *World fresh vegetable trade increased more than fourfold between 1962 and 1982. The major trading areas include virtually the entire world—Latin America, the United States, Canada, the European Community, the Middle East, the Far East, Africa, and the non-EC Western European nations. An Armington-type model is constructed here to represent the forces driving world vegetable trade and their relative strengths between regions. The parameter estimates are then used to simulate the effects of the U.S.-Canadian Free Trade Agreement (FTA) on fresh vegetable trade between the countries. Results indicate that aggregate national vegetable demand in both countries will show larger increases with enactment of the trade agreement than without its enactment.*

Keywords. *Vegetable trade, market demand functions, product demand functions, Armington model, constant ratio of elasticities of substitution, Free Trade Agreement, simulations.*

International trade in fresh vegetables has become increasingly important to both developed and developing nations. Exports of fresh vegetables among major trading regions increased from 3.6 million metric tons in 1962 to nearly 14.5 million metric tons in 1982 (table 1). The fastest growing import markets were Western Europe, the Far East, Africa, and the Middle East. While fresh vegetable trade increased 400 percent, production grew less than 150 percent. The Middle East experienced the strongest production growth, as well as significant increases in imports. The Far East showed the strongest growth in exports of fresh vegetables, while production grew by less than the world average. Changes in fresh vegetable trade are influenced by factors beyond expanding supplies, including regional demand and agricultural trade policies designed to enhance product competitiveness.

Table 1—Growth of global imports and exports of vegetables, 1962-82

Item	1962	1982	Percentage gain
	Metric tons		*Percent*
Imports:			
Latin America	204,453	225,246	1.10
United States	315,787	1,411,592	3.62
Canada	464,714	679,947	1.46
Western Europe[1]	2,463,681	11,540,888	4.68
Middle East	54,086	198,499	3.67
Far East	73,205	536,520	7.33
Africa	120,444	504,027	4.18
World imports	3,693,370	14,826,719	4.01
Exports:			
Latin America	341,001	997,392	4.14
United States	680,314	1,458,805	2.14
Canada	252,491	684,132	2.71
Western Europe	1,534,126	2,481,683	1.62
Middle East	180,860	707,811	3.91
Far East[2]	109,873	7,729,112	70.35
Africa	666,741	375,745	.56
World exports	3,595,509	14,434,680	4.01

[1]The EC and non-EC Western European regions are not presented separately because, although the countries in Europe considered in this analysis did not change, their status as EC members may have. Thus, the composition of the two regions changed from 1962 to 1982. If the two regions were presented separately, it would be unclear as to what had caused growth or lack of growth: expansion in members or a change in the level of participation in trade. The important issue in this table is the absolute level of change in European interregional trade.

[2]1962 was an abnormally low year for the Far East, so we used the 1963 level.

To better understand vegetable trade flows, we designed a world trade model based on regional demands and supplies. We surveyed Latin America, the United States, Canada, the European Community (EC), the Middle East, the Far East, Africa, and the non-EC Western European nations. We included these regions because of the volume and dollar levels of participation in the international trade of fresh vegetables. Fresh vegetables are defined to encompass fresh potatoes, dried beans, peas, lentils and leguminous vegetables (SITC 054.1); fresh tomatoes, other fresh vegetables (054.4); vegetables frozen or in temporary preservative (054.5); and vegetable products (054.8) (United Nations Standard International Trade Codes). The estimated model simulates the effect of the U.S.-Canadian Free Trade Agreement on fresh vegetable trade between these two countries.

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This is a high level of aggregation, but its use is justified for two reasons.[1] The purpose of this study is to understand the nature and strength of the forces driving international trade in fresh vegetables in general. Second, the composition of the vegetable trade between regions did not vary by much during the time period examined (1962-82). That is, the percentages of the total trade flow between any two regions composed of 054.1, 054.4, 054.5, and 054.8 remained relatively constant. Consequently, it is justifiable to speak in terms of one good per trade partner when dealing with the international flow of fresh vegetables during 1962-82.

Theoretical Trade Model

The theoretical framework for the current model follows Armington (1969).[2] There are several assumptions underlying this model, one of which is that consumer choice occurs in two stages. The first decision, which determines the total level of consumption for each commodity (market demands), is based upon commodity prices, income levels, substitute commodity prices, and other relevant economic variables. The second step is to decide whether to buy the product. That is, once the total consumption level for each commodity has been determined, an allocation among the different suppliers (product demands) has to be made. A goods category like vegetables is composed of products that are distinguished by their place of origin. The products within a goods category are not perfect substitutes but are close enough to remain in the same product group (Hickman and Lau, 1973; Houthakker and Magee, 1969).

Another important assumption of the model is that import demands are homothetic and separable among import sources. Armington's demands for products within each good's market are assumed independent of those demands for products in other good's markets. Thus, markets for goods can be empirically distinguished. Within a market, product shares are affected by changes in the size of a market and changes in relative prices. The prices of competing goods affect product demands in other goods' markets only indirectly through their influence on the total market size and average market prices.

While these assumptions factor into a two-stage budgeting model, like the Armington model, they do not always hold (Alston and others, 1990). Nevertheless, the Armington model offers the advantage of a relatively small number of parameters to estimate as compared with some other types of models. In trade models with several products, the number of parameters to be estimated can be inordinately large. Armington dealt with this problem by defining a fixed technical rate of substitutability among the products for a given region. His theoretical model assumed the elasticities of substitution between competing products to be constant and equal, thus giving one elasticity of substitution for each good's market. In contrast, Artus and Rhomberg (1973) assumed that the ratio of the elasticities of substitution for all products competing in a good's market vary by a constant proportion but noted that the substitutability between every product is not necessarily identical. Both models impose restrictions on the system, facilitating the estimation process.

All vegetable types are aggregated here into a single vegetable category (good), and vegetable products are distinguished by place of production. Quality differences can be one of the major factors affecting the distribution of vegetable imports. Given likely quality differences, an assumption that all vegetable products have the same elasticity of substitution is unduly restrictive. Artus and Rhomberg's (1973) use of the constant ratio of elasticity of substitution (CRES) is less restrictive. The imposition of the CRES technical relationship on the vegetable trade system can be used to derive import demands for goods from region j demanded by region i.

Define $X_{i\cdot}$ to be consumption of X in region i and X_{ij} to be the demand in region i for the product from region j. The size of the market demand ($X_{i\cdot}$) is affected by income, population, and the price of the good. Using the aggregate demand and the CRES specification, product demands (X_{ij}) are some function of the market demand ($X_{i\cdot}$) and the price of the product relative to the average market price of vegetables, $X_{ij} = f(X_{i\cdot}, P_{ij}/P_{i\cdot})$. In this case, the product demand X_{ij} can be estimated using only two right-hand side variables.

Imposing the CRES technical relationship in equation 1 and the market-clearing condition that the marginal rates of substitution between competing products be equal to their price ratios, the product demand functions (see appendix) follow:

$$X_{i\cdot} = \{\textstyle\sum_j \beta_{ij} X_{ij}^{\alpha_{ij}}\}^{(1/\alpha_{i\cdot})}, \qquad (1)$$

[1]For additional information on fruit and vegetable trade at this level of aggregation, see Alexander H. Sarris, "European Community Enlargement and World Trade in Fruits and Vegetables," *American Journal of Agricultural Economics,* May 1983, Vol. 65, pp. 235–46.

[2]Sources are listed in the References section at the end of this article.

and

$$X_{ij} = (D_{ij})^{\tau_{ij}}(P_{ij}/P_{i.})^{\tau_{ij}}(X_{i.})^{(\alpha_{i.}-\tau_{ij})}, \tag{2}$$

where $D_{ij} = (\alpha_{i.}/\alpha_{ij})\beta_{ij}$ and $\tau_{ij} = 1/(\alpha_{ij}-1)$. Equation 2 can be readily quantified within the context of the total trade model.

Prices are the crucial linking mechanism of the model, serving to allocate products among markets. There are three relevant prices linking the trade flows. The export price (F_{ij}) is the price at the point of export from region j, destined for market i. $F_{.j}$ is the average free-on-board export price in market j. Import prices (C_{ij}'s) differ from the F_{ij}'s and should be influenced by quality differences, market structures within the goods market, the costs of insurance and freight, and nontariff barriers. P_{ij} is the market price in region i for product from region j. This price includes the costs of tariffs and preferential treatments.

All prices are expressed in U.S. dollars, thus accounting for exchange rate variability. In the appropriate situations, the prices are deflated by the U.S. consumer price index (CPI). The CPI base year is 1962. In the list of equations, we have designated the prices that are deflated.

The average export price is represented by:

$$F_{.j} = \textstyle\sum_j (F_{ij}\, X_{ij})/X_{.j}. \tag{3}$$

A product produced and consumed domestically does not incur costs associated with shipping and barriers to entry such as tariff and nontariff barriers. That product's price is assumed to be equal to the average of all export prices for that producing region.

Regional import prices are functionally related to the export price and proxy trend variable designed to capture increasing distribution costs over time, (Z):

$$C_{ij} = C(F_{ij}, Z). \tag{4}$$

Import prices are adjusted by the tariff rates in order to derive the price of product j in market i. Data limitations prevent calculating distribution costs within a goods market:

$$P_{ij} = (1 + T_{ij})\, C_{ij}. \tag{5}$$

T_{ij} represents tariffs that region i applies to imports from region j and are expressed in percentage terms. The average price paid for vegetables in region i is defined as:

$$P_{i.} = \textstyle\sum_j (P_{ij}\, X_{ij})/X_{i.}. \tag{6}$$

To assure that the system is in equilibrium, demand and supply restrictions are placed on the model where $X_{i.} = \sum_i X_{ij}$ and $X_{.j} = \sum_i X_{ij}$.

Each functional equation is specified in multiplicative form while the equilibrium restrictions are additive. The multiplicative forms were based on theoretical expectations and designed to conform with product demand functional forms obtained by the imposition of the CRES technical relationship. The complete system is shown below with the functions in their log linear form on a per capita basis.

Market demand

$$\ln\,(X_{i.}/Pop_i) = \delta_{0i} + \delta_{1i}\,\ln(P_{i.}/CPI) + \delta_{2i}\,\ln(GDP_i/CPI) \tag{7}$$

Product demand

$$\ln X_{ij} = \Theta_{0ij} + \Theta_{1ij}(\ln P_{ij} - \ln P_{i.}) + \Theta_{2ij}\ln X_{i.} \tag{8}$$

Export supply

$$\ln(X_{.j} - X_{jj}) = \phi_{0j} + \phi_{1j}\ln(F_{.j}/CPI) + \phi_{2j}\ln X_{.j} \tag{9}$$

CIF import price

$$\ln C_{ij} = \Phi_{0ij} + \Phi_{1ij}\ln F_{ij} + \Phi_{2ij}\ln Z_{ij} \tag{10}$$

Average market price

$$P_{i.} = \textstyle\sum_j (P_{ij}\, X_{ij})/X_{i.}. \tag{11}$$

Average FOB export price

$$F_{.j} = \textstyle\sum_i (F_{ij}\, X_{ij})/X_{.j} \tag{12}$$

Market price

$$P_{ij} = (1 + T_{ij})\, C_{ij} \tag{13}$$

Domestic demand

$$X_{ij} = X_{.j} - X_{ij} \tag{14}$$

Supply restriction

$$X_{.j} = \textstyle\sum_i X_{ij} \tag{15}$$

Demand restriction

$$X_{i.} = \textstyle\sum_j X_{ij}, \tag{16}$$

where $i \neq j$, Θ_{1ij} corresponds to τ_{ij}, Θ_{0ij} corresponds to $(D_{ij})^{\tau_{ij}}$, and Θ_{2ij} corresponds to $(\alpha_{i.} - \tau_{ij})$.

The variables are as follows:

$X_{\cdot j}$ = total vegetable production in market j
$X_{i\cdot}$ = total market demand for vegetables in market i
$P_{i\cdot}$ = average market price for vegetables in market i
X_{ij} = demand for the jth vegetable product in market i
P_{ij} = jth vegetable product's price in the ith market
C_{ij} = jth vegetable product's cost of insurance and freight price in market i
F_{ij} = jth vegetable product's free-on-board price bound for market i
$F_{\cdot j}$ = average free-on-board price received by region j for its product
X_{jj} = demand for vegetables from domestic sources
GDP_i = gross domestic product in region i
CPI = U.S. Consumer Price Index to the base year of 1962.

This system of equations is linear in the parameters but nonlinear in many of the variables. Equations 11-16 are identities and are always just identified. The functional relationships, equations 7-10, are all overidentified. Their estimation calls for a systems approach.[3] Estimation is with nonlinear two-stage least squares using annual data from 1962 through 1982. Given the short time series and large number of exogenous variables, it is impossible to estimate the first stage using all exogenous variables as instruments. Hence, first-stage estimates are based on using principal components over the exogenous variables. The first five principal components serve as instruments.[4]

Trade Model Estimates

The trade model was estimated simultaneously for the eight regions/countries. Elasticity estimates are presented in tables 2 and 3 for market demand, product demand, export supply, and CIF import price equations. Income and market-share elasticities for market and product demand equations are in table 4. Table 5 shows production-level and distribution cost elasticities from the export supply and CIF import price equations. Statistics regarding the fit and performance of the model indicate that the equations do a reasonable job representing the economic forces involved in fresh vegetable trade. The R^2 and t-statistics varied considerably across the equations.

The empirical results for the market demand relationships (equation 7) indicate that all regions except Africa show a negative price response (table 2). The t-statistic is small for Africa, indicating that the parameter is statistically insignificant. The t-statistic for Latin America indicates that price is an insignificant variable in explaining its market demand for fresh vegetables. For all other regions, the price parameters are negative, statistically significant, and inelastic, except for the Middle East and Canada, which are elastic.

Price elasticities for product demands in general show negative price responses (table 2). Elasticities with positive price relationships usually have small t-statistics. All regions except the Far East have negative price responses to U.S. vegetables, and the Far East's parameter is insignificant. These price elasticities are all elastic except Canada's inelastic response. The results indicate that Latin America, the EC, the Middle East, Africa, and the non-EC Western European region will increase their imports of U.S. vegetables proportionately more than any drop in price that may occur for these vegetables. Canada, the largest U.S. vegetable market, is relatively unresponsive to price changes for U.S. vegetables.

Of U.S. vegetable demands, only those for Latin America, the Middle East, and the Far East have statistically significant price elasticities. The U.S. demand for Latin American vegetables is inelastic, and demands for Middle Eastern and Far Eastern vegetables are unitary elastic. These results indicate that price does not play a strong role in determining levels of U.S. vegetable demand.

Export supply price elasticities are all positive and statistically significant except those for the United States (negative) and the Middle East (insignificant) (table 3). Elasticities for the Far East, Latin America, and the non-EC Western European region are elastic, with the Far East quite elastic at 10.61. All three of these regions will substantially increase their vegetable exports with increases in the prices they receive. In contrast, Africa, the EC, and Canada have inelastic export supply responses to price. Results indicate that these regions will show only small increases in their export supplies with increases in the prices they receive.

[3]We first applied nonlinear three-stage least squares to the problem. However, the contemporaneous variance-covariance matrix of the disturbances of the structural equations was virtually diagonal, so the third-stage estimation was not useful.

[4]The trade model has 82 exogenous variables and 21 degrees of freedom. A standard instrumental variable technique would exceed the degrees of freedom and would not be a feasible method of estimating the first stage of the simultaneous system. The first five principal components account for 98 percent of the variation in the explantory exogenous variables (Theil, 1978; Pindyck and Rubinfeld, 1981; Sparks, 1987).

Table 2—Price elasticities from market and product demand equations

Item	Latin America	United States	Canada	European Community	Middle East	Far East	Africa	Non-EC Western Europe
Market demand price elasticities	–0.63	–0.347	–5.049	–0.784	–1.200	–0.463	0.032	–0.182
	(–1.12)[1]	(–2.094)	(–5.049)	(–4.637)	(–2.817)	(–1.355)	(1.219)	(–2.179)
Product demand relative price elasticities:[2]								
Latin America		–1.332	1.986	–.859	–2.767	–2.847	–2.344	–1.014
	( )	(–1.466)	(1.172)	(–1.158)	(–2.477)	(–1.848)	(–1.610)	(–1.303)
United States	–.611		–.165	–.090	–1.043	–1.035	–.710	–.475
	(–2.787)	( )	(–.319)	(–.580)	(–1.638)	(–2.248)	(–1.164)	(–.868)
Canada	–.498	–.497		–.254	–.579	.050	.241	–.922
	(–3.386)	(–4.923)	( )	(–.656)	(–.418)	(.125)	(.142)	(–1.841)
European Community	–.416	–3.217	1.223		–4.797	–3.906	.012	1.850
	(–.557)	(–4.046)	(1.068)	( )	(–7.042)	(–15.155)	(.015)	(2.932)
Middle East	1.580	–1.576	.233	–2.012		–1.224	–1.210	–2.256
	(1.452)	(–1.373)	(.205)	(–4.254)	( )	(–3.421)	(–.878)	(–4.069)
Far East	.118	.482	–.849	–.415	–2.525		–.436	–.108
	(.103)	(1.258)	(–.839)	(–1.201)	(–3.805)	( )	(–1.153)	(–.211)
Africa	–1.483	–2.706	–1.011	–1.314	–.635	–1.559		–2.360
	(–1.166)	(–2.692)	(–1.151)	(–1.027)	(–.868)	(–1.155)	( )	(–2.710)
Non-EC Western Europe	1.003	–3.741	3.582	2.770	–3.312	.005	–3.951	
	(3.100)	(–3.941)	(7.398)	(3.929)	(–9.414)	(.010)	(–6.112)	( )

[1]t-statistics in parentheses.
[2]Region i is down the first column and region j is across the top row. Thus, the numbers indicate X_{ij}.
Blanks = not applicable.

Table 3—Price elasticities from export supply and CIF price equations

Item	Latin America	United States	Canada	European Community	Middle East	Far East	Africa	Non-EC Western Europe
Export supply price elasticities	3.627	–0.781	0.3312	0.524	0.131	10.612	0.688	1.688
	(4.955)[1]	(–1.165)	(2.337)	(1.972)	(.552)	(3.420)	(3.381)	(6.997)
CIF-FOB price linkage elasticities:[2]								
Latin America		.653	.524	1.088	1.003	–.079	.723	.605
	( )	(1.656)	(3.529)	(6.787)	(2.465)	(–.584)	(4.629)	(3.386)
United States	–.702		.884	.934	1.112	1.368	.578	1.255
	(–3.153)	( )	(4.933)	(4.268)	(1.712)	(2.548)	(2.200)	(1.473)
Canada	–.543	.768		.094	.604	.892	.652	2.000
	(–5.501)	(5.294)	( )	(2.674)	(2.377)	(1.367)	(1.984)	(3.590)
European Community	.882	.627	.916		.202	1.329	1.071	1.164
	(3.732)	(2.128)	(5.088)	( )	(.393)	(8.701)	(4.090)	(2.903)
Middle East	1.020	1.841	.919	1.084		1.319	.832	.997
	(1.151)	(1.980)	(2.772)	(4.104)	( )	(2.073)	(2.194)	(6.181)
Far East	.719	.748	.098	.842	.139		.735	.830
	(1.746)	(5.978)	(.129)	(2.049)	(.508)	( )	(2.351)	(3.342)
Africa	1.221	.117	1.279	.759	.699	.007		1.672
	(3.170)	(.227)	(2.895)	(3.925)	(1.605)	(.016)	( )	(4.119)
Non-EC Western Europe	.336	1.052	.461	1.069	1.094	1.143	.850	
	(2.613)	(5.388)	(1.169)	(4.051)	(7.385)	(4.432)	(7.418)	( )

[1]t-statistics in parentheses.
[2]Region i is down the first column and region j is across the top row.
Blanks = not applicable.

Production-level elasticities for the export supply equations indicate that only non-EC Western Europe and Latin America will substantially increase their vegetable exports as their production increases (table 4). Canada's production elasticity is slightly larger than unity while those for the EC and the Middle East are inelastic. Africa's coefficient even suggests that exports of fresh vegetables will actually decrease with increases in production.

Table 4—Production level and distribution cost elasticities for export supply and CIF price equations

Item	Latin America	United States	Canada	European Community	Middle East	Far East	Africa	Non-EC Western Europe
Export response elasticities	4.488	0.897	1.146	0.835	0.528	2.490	–2.034	2.138
to production	(2.782)[1]	(1.241)	(5.563)	(1.319)	(4.889)	(1.076)	(–7.809)	(4.533)
CIF response elasticities to costs:[2]								
Latin America		18.815	117.280	–3.460	–141.790	159.470	79.203	78.258
	( )	(.338)	(4.341)	(–.117)	(–1.404)	(6.442)	(3.272)	(2.528)
United States	219.150		12.393	15.100	84.358	30.669	–36.246	–36.256
	(6.095)	( )	(.416)	(.576)	(1.755)	(.744)	(–.403)	(–.430)
Canada	225.600	62.672		–45.401	61.205	52.297	91.639	–303.180
	(11.003)	(3.317)	( )	(–1.136)	(1.154)	(.873)	(1.270)	(–2.450)
European Community	33.699	55.974	.854		101.850	–95.771	30.740	–50.709
	(.888)	(1.352)	(.018)	( )	(1.747)	(–4.375)	(826)	(–.599)
Middle East	183.700	–60.305	13.611	–27.388		55.774	70.624	125.810
	(1.534)	(–.444)	(.246)	(–.463)	( )	(.573)	(1.382)	(3.767)
Far East	120.850	62.672	91.783	36.468	84.833		87.146	6.067
	(1.253)	(2.904)	(.707)	(.520)	(1.924)	( )	(1.236)	(.256)
Africa	–7.176	81.079	–2.662	21.326	–12.164	115.040		–48.219
	(–.156)	(1.218)	(–.081)	(.606)	(–.148)	(1.798)	( )	(–.766)
Non-EC Western Europe	141.730	15.499	63.253	–20.627	35.135	72.482	57.426	
	(4.965)	(.496)	(1.669)	(–.488)	(1.202)	(2.986)	(2.449)	( )

[1] t-statistics in parentheses.
[2] Region i is down the first column and region j is across the top row.
Blanks = not applicable.

There is a statistically significant relationship between the CIF and FOB prices for most vegetable products (table 3). This relationship, in some instances, is negative. However, much of the volatility in CIF prices for all regions appears to reflect changes in transportation and handling costs as reflected in the time-trend variable (table 4). In contrast, the FOB prices appear to have less effect on CIF prices.

GDP is used as a measure of income. The income elasticities in the market demand equations are all inelastic, and only four are statistically significant: Canada, the EC, the Middle East, and Africa (table 5). The negative income elasticities are very small, –0.11 for the EC and –0.04 for Africa. In these cases, it appears that income has a slight negative effect on the demand for fresh vegetables. In Canada and the Middle East, income has a very small but positive influence on demand.

Market share elasticities in the product demand equations are statistically significant approximately 50 percent of the time (table 4). U.S. product demand market share elasticities are significant and positive for vegetables from Latin America, Canada, Middle East, and Africa. They are also highly elastic. As the U.S. aggregate demand for vegetables increases, its demand for vegetables from these regions increases dramatically. U.S. demands for EC and non-EC Western European vegetables, however, are not responsive to the size of its vegetable market. In these cases, price is the more dominant variable in determining levels of demand.

Market-share elasticities of demand for U.S. vegetables are positive and statistically significant for Canada, the Middle East, the Far East, Latin America, and Africa. Middle East demand is unitary elastic, Canada's is slightly more than unitary elastic, while Africa and the Far East have very elastic market size responses to U.S. vegetables. Vegetable market size does not affect the EC and the non-EC Western European region's demands for U.S. vegetables. Price is the dominant variable there.

Simulation of the Impact of the U.S.-Canadian Free Trade Agreement

Large models as estimated in this study probably are best used to simulate policy issues like the effect of the U.S.-Canadian Free Trade Agreement (FTA) on vegetable trade between the two countries. The FTA simulations, here completed on an equation-by-equation basis, give only a partial analysis of trade adjustments. The reason for the partial analysis is because the system is very large and highly nonlinear. Hence, reduced forms of equations were not derived.

Table 5—Income and market share elasticities from market and product demand equations

Item	Latin America	United States	Canada	European Community	Middle East	Far East	Africa	Non-EC Western Europe
Market demand income elasticities	–0.060	0.106	0.408	–0.111	0.686	1.200	–0.039	0.045
	(–.645)[1]	(1.127)	(5.878)	(–1.522)	(5.506)	(.587)	(–2.522)	(.581)
Product demand market-share elasticities:[2]								
Latin America		1.246	.432	3.379	.751	1.422	2.128	3.627
	( )	(1.017)	(.133)	(2.622)	(.181)	(.632)	(1.124)	(3.951)
United States	4.210		1.551	–.227	9.361	3.457	2.232	–1.239
	(11.167)	( )	(1.436)	(–.371)	(4.918)	(2.470)	(2.221)	(–1.356)
Canada	.437	1.161		1.292	8.032	3.459	–1.991	–1.926
	(1.183)	(8.898)	( )	(1.194)	(4.094)	(3.533)	(–.642)	(–1.705)
European Community	–3.115	–.686	–4.309		–1.781	–.833	–.009	–.188
	(–1.488)	(–.471)	(–.985)	( )	(–1.106)	(–.603)	(–.013)	(–.172)
Middle East	.881	1.029	1.906	1.773		3.800	.820	.723
	(.780)	(2.181)	(3.837)	(6.123)	( )	(5.098)	(1.817)	(1.521)
Far East	–1.051	5.164	13.764	2.680	–.985		–2.250	4.634
	(–.234)	(8.603)	(4.656)	(3.836)	(–.321)	( )	(–1.946)	(2.391)
Africa	15.875	3.479	7.075	2.456	6.257	2.929		.016
	(7.625)	(1.682)	(2.754)	(4.018)	(5.988)	(1.345)	( )	(.019)
Non-EC Western Europe	2.155	–.090	.734	–.007	2.929	–7.024	2.907	
	(2.229)	(–.040)	(.410)	(–.013)	(1.730)	(–1.461)	(1.080)	( )

[1]t-statistics in parentheses.
[2]Region i is down the first column and region j is across the top row.
Blanks = not applicable.

The United States and Canada are each other's largest export markets. The FTA, which became effective January 1, 1989, will eliminate U.S.-Canadian bilateral tariffs over a period of 10 years. Economic theory suggests that the probable effect of this agreement will be to increase competition between the two countries. U.S.-Canadian agricultural trade is substantial: 6 percent of U.S. agricultural exports went to Canada in 1987 and 11 percent of U.S. agricultural imports were from Canada.[5] Agricultural trade with the United States accounted for 6 percent of Canada's agricultural exports and 55 percent of agricultural imports in 1987. Vegetables, including roots and tubers, constitute a significant proportion of this trade. In 1987, 12 percent of U.S. agricultural exports to Canada and 4 percent of its agricultural imports from Canada were vegetables. In the same year, vegetables made up 5 percent of Canadian agricultural exports and 17 percent of agricultural imports from the United States.

International trade in fresh vegetables more than quadrupled from 3.7 million metric tons (mmt) in 1962 to 14.8 mmt in 1987. Neither U.S. nor Canadian participation grew at a comparable rate. U.S. vegetable imports increased more than 5.6 times, from 0.3 mmt to 1.8 mmt during the 25-year period. At the same time, U.S. vegetable exports grew from 0.7 mmt to 1.2 mmt. Canadian imports of vegetables grew from 0.5 mmt to 1.3 mmt (data on Canada from 1989; 1987 data unavailable), a 160-percent increase. Canadian exports increased from 0.3 mmt to 1.0 mmt (1963 data were substituted for unavailable 1962 data).

Canada has reduced its imports of vegetables from the United States, from 92 percent of all vegetable imports in 1962 to 89 percent in 1989. The balance was almost totally supplied by Latin America and the EC. Canadian exports bound for the United States, on the other hand, increased from 40 percent to 53 percent of Canada's total vegetable exports over the same period. While U.S. participation in world vegetable trade has increased, the share of U.S. vegetable exports going to Canada has fallen. U.S. exports to Canada declined from 56 percent to 39 percent of total U.S. vegetable exports between 1962 and 1989.

The United States primarily imports potatoes ($41.7 million), potato seeds ($18.5 million), carrots ($5.9 million), and onions ($3.9 million) from Canada (Bureau of Census, 1990). In contrast, Canada imports most types of U.S. vegetables.

Restrictions on Vegetable Trade

The United States and Canada employ tariffs on fresh vegetables to protect domestic producers. The

[5]The latest U.N. trade data available for the United States are for 1987.

tariffs were at modest levels in 1989, ranging from 15-20 percent of a product's value for the United States and 10-15 percent for Canada. Canada's tariffs on vegetables are seasonal and apply only during production months. The U.S.-Canadian FTA began eliminating tariffs at a rate of 10 percent per year in 1989. However, a 20-year provision allows tariffs to snap back to their pre-agreement level, if imports threaten the domestic industry. The snapback provision must meet four conditions. First, import prices must be below 90 percent of the preceding 5-year monthly average for 5 working days. The highest and lowest years would be excluded from consideration. Second, planted acreage may not be higher than the previous 5-year average, again excluding the highest and lowest years. Third, the combined temporary and normal duty may not exceed that for most favored nation status. Finally, the temporary duty may be applied only once in a 12-month period (Normile and Goodloe, 1988). Once applied, the snapback duty will be rescinded if prices go above 90 percent of the preceding 5-year monthly average for 5 working days, or failing that, it will automatically be rescinded after 180 days.

The bilateral agreement does not establish a free-trade situation between the two countries, but merely addresses the tariff issue. However, tariffs are the primary means of restricting vegetable trade between the United States and Canada. While regulations imposed by some marketing orders (mainly potatoes and onions from Canada) within the United States also apply to imports from Canada, the regulations are readily available and consequently can be conformed to by exporters. This is equally true of regulations imposed by the Canada Agricultural Products Act (CAP Act), which applies both to Canadian and imported produce. (The CAP Act regulates the marketing of agricultural products in import, export, and interprovincial Canadian trade, providing for national standards and grades of agricultural products and for their inspection and grading.) Given that tariffs are the primary impediment to vegetable trade between the United States and Canada, their reduction and elimination would seemingly increase vegetable trade between the two countries.

The FTA is assumed to have a negligible impact on U.S. and Canadian vegetable trade with the six other regions. This is a broad assumption and is largely justified. The possible exception is Mexico, from whom the United States and Canada import a large percentage of their vegetables. However, the economic incentive of the FTA is such that the United States and Canada would purchase more vegetables from each other and less from other sources, including Mexico. To ascertain how the FTA affects U.S. and Canadian vegetable trade with Mexico, the model would have to be re-estimated. This is because Mexico was indistinguishable from the rest of Latin America in the original regional delineations. With respect to the U.S.-Canadian FTA, the specific inclusion of Mexico is not necessary for an accurate assessment of the agreement's impact on the United States and Canada, the two countries that would be primarily affected by the agreement.

Simulation Results

Two sets of simulations were conducted. In the first baseline simulation, GDP, and population levels for both the United States and Canada were allowed to grow for 10 years. The growth simulated the actual level of expansion one would expect based on historical trends in these two variables for each of the countries.[6] GDP levels were simulated to increase by 3 percent and population by 1 percent per year in each country.

To carry out the first set of simulations, GDP and population were allowed to grow along the trends described. They were then multiplied by the estimated parameters and the levels of market demand obtained. These simulated levels of market demand were then multiplied by the estimated parameters of the product demand equations to obtain simulated levels of product demand.

In the second simulation, GDP and population levels were allowed to grow while U.S.-Canadian tariff levels were reduced by 10 percent per year. This was accomplished by reducing product prices by 10 percent of the average tariff assessed on fresh vegetables in Canada and the United States and average market prices by somewhat smaller amounts for each of 10 years.[7] These values of GDP, population, and tariffs were then multiplied by the parameter estimates of the market and product demand equations to obtain the simulated levels of demand.

[6]1989 real GNP growth: U.S. 2.9 percent; Canada 2.6 percent (International Monetary Fund, 1989). 1980-88 average annual change in U.S. population, 1.1 percent (International Monetary Fund, 1990). 1983-89 average annual change in Canadian population, 0.9 percent (International Monetary Fund, 1989).

[7]The average market prices were lowered by a percentage accounting for the tariff reduction and a percentage accounting for the share U.S. or Canadian vegetables hold in the market. For the United States, this second percentage was 0.991, or 100 – (0.30 * 0.03) where 0.30 is the percentage of vegetable imports received from Canada and 0.03 is the percentage of total demand supplied by imports. For Canada, the second percentage was 0.8884, or 100 – (0.93 * 0.12). Ninety-three percent of Canadian imports are supplied by the United States. Twelve percent of the Canadian market is composed of imports.

Due to the method used in obtaining the results, the simulated levels of demand are very sensitive to the size of the parameters. The parameters, however, were estimated from the U.N. trade data and are good representations of the demand relationships in U.S.-Canadian vegetable trade. Consequently, the simulations should be relatively accurate representations of the implications of the FTA for bilateral fresh vegetable trade.

Percentage differences between the levels of U.S. market demand simulations increase linearly as the simulation horizon increases (fig. 1). The difference ranges from 0.9 percent in the first year of the simulated FTA to 7 percent in the 10th and final year of the bilateral tariffs. These numbers indicate that the U.S.-Canadian FTA could result in a 7-percent increase in the U.S. market demand for vegetables. Simulations in which tariffs are not lowered but GDP and population are increased indicate that the U.S. market demand for vegetables will be 52 mmt by the 10th year. Simulations in which tariffs are lowered indicate that the U.S. market demand will be approximately 56 mmt.

The percentage differences in the Canadian market demand simulations are larger than those for the United States (fig. 2). They range from 6.3 percent in the first year to 12.7 percent in the final year of the tariff reductions. However, while the percentage differences are larger, the absolute quantities expected to be demanded are smaller than U.S. quantities. Without the tariff reduction, simulations indicate that approximately 7 mmt of fresh vegetables will be demanded by Canada in the 10th year. With the tariff reduction, demand would be approximately 8 mmt.

U.S. demand for Canadian vegetables is simulated to increase by 10.9 percent above the baseline as a result of the reduction in tariffs (fig. 3). Without the tariff reduction, with expected GDP and population increases, the United States could be expected to demand 262,000 metric tons (mt) of Canadian vegetables in the 10th year of the simulation. With the reduction in tariffs, that demand is expected to be 290,000 mt.

In contrast, the percentage increase in Canada's demand for U.S. vegetables would likely be smaller (fig. 4), but the quantities would be much larger than those of U.S. demand for Canadian vegetables. The percentage difference between the baseline and the tariff reduction simulations is 8.4 percent. The quantities expected to be demanded without the

Figure 1
Effect of tariff reduction on U.S. demand for fresh vegetables

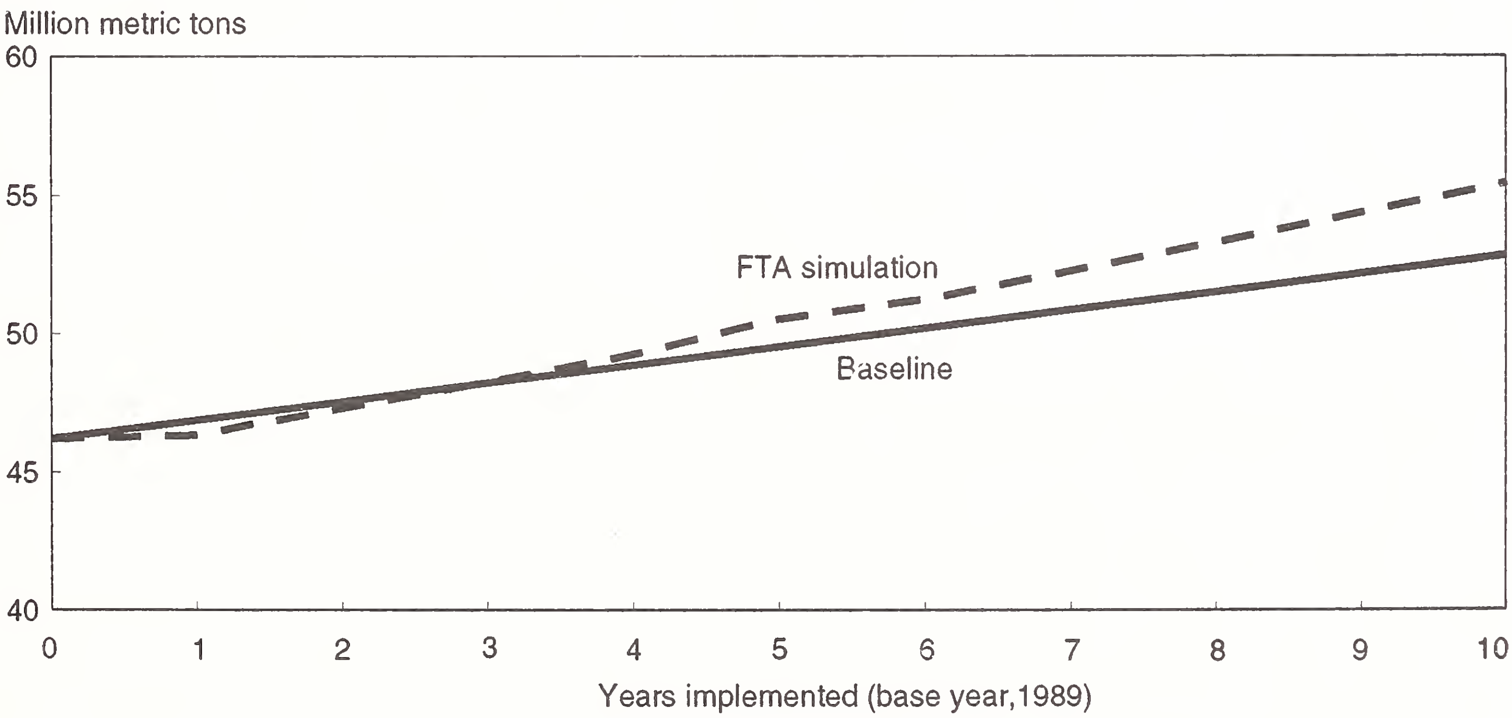
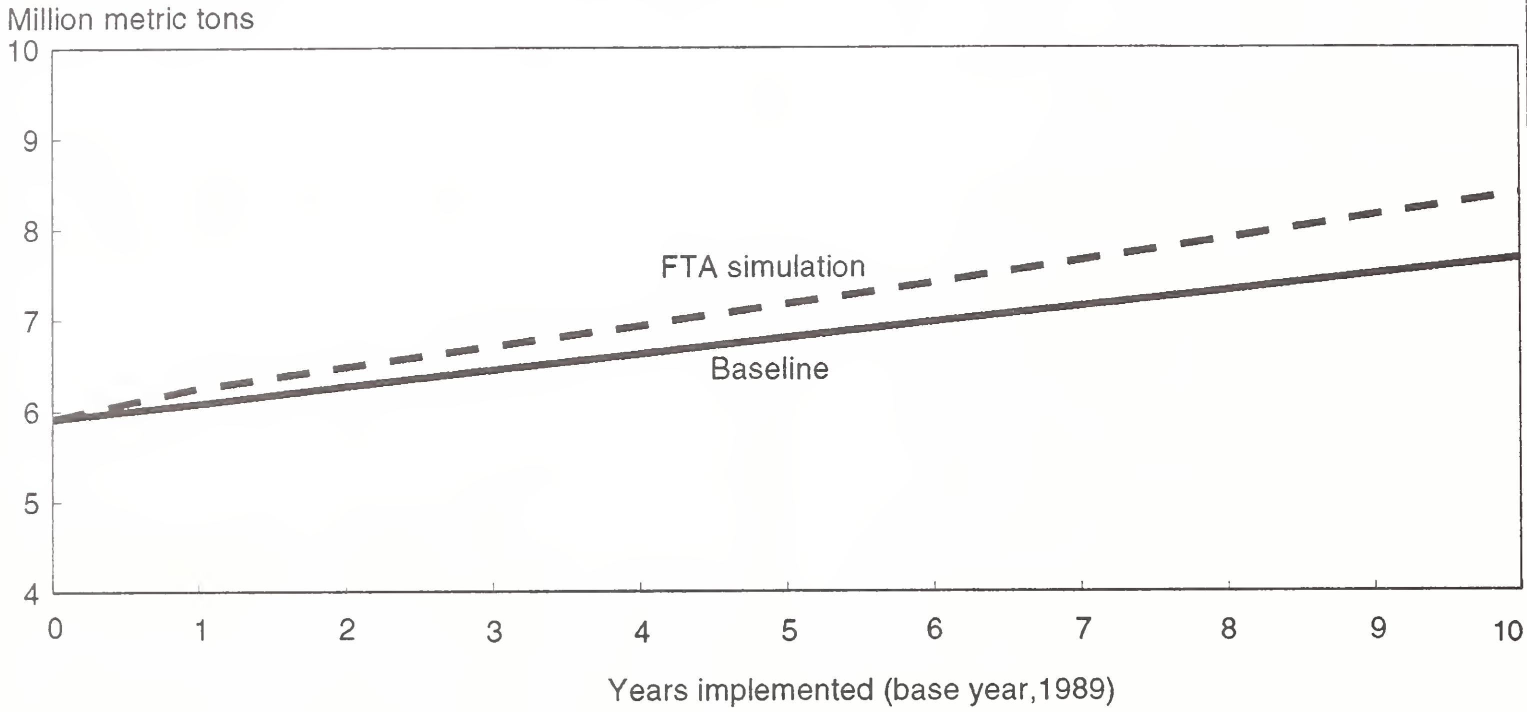


Figure 2

Effect of tariff reduction on Canadian demand for fresh vegetables



tariff reduction are 868,000 mt, as opposed to 940,000 mt with the tariff reduction.

Conclusions

International trade of fresh vegetables more than quadrupled between 1962 and 1982 while production less than doubled. The patterns of trade increases did not conform to the simple presence of supply. Given the large increases in trade and the relatively small increases in production, we hypothesized that vegetable trade was driven primarily by demand.

Empirical results of the world trade model indicate that as GDP levels grow, the Middle East and Canada will increase their demand for fresh vegetables substantially. Thus, if the price of oil increases, it is likely that Middle Eastern demand for fresh vegetables will follow GDP growth and increase. Other regions—Latin America, the United States, the Far East, and the non-EC Western European region—show a smaller response to GDP. Policies designed to increase incomes in areas other than Canada and the Middle East may not have much effect on demand for fresh vegetables.

U.S. demand for vegetables from Latin America and Canada shows a negative relationship to the market price. These results indicate that the U.S.-Canadian Free Trade Agreement, which lowers tariffs between these countries, will likely result in more vegetable imports from Canada. The North American Free Trade Agreement (NAFTA) would also likely increase U.S. demand for Canadian and Latin American vegetables. Because Latin America and Canada also have negative price responses to U.S. vegetables, NAFTA would likewise increase their demand for U.S. vegetables.

The two European regions' demands for U.S. vegetables are very responsive to the price of the product. Any negotiations that lowered the CAP levy on imports of U.S. vegetables would have the effect of increasing EC demand for these vegetables. Because the EC is a major vegetable market, success with lowering the CAP levy would boost demand for U.S. vegetables.

Simulations to measure the effect of the U.S.-Canadian FTA indicate that both aggregate national demand and bilateral vegetable demand will show larger increases with enactment of the trade agreement than without its enactment. The U.S.

Figure 3
U.S. demand for Canadian vegetables under simulated FTA

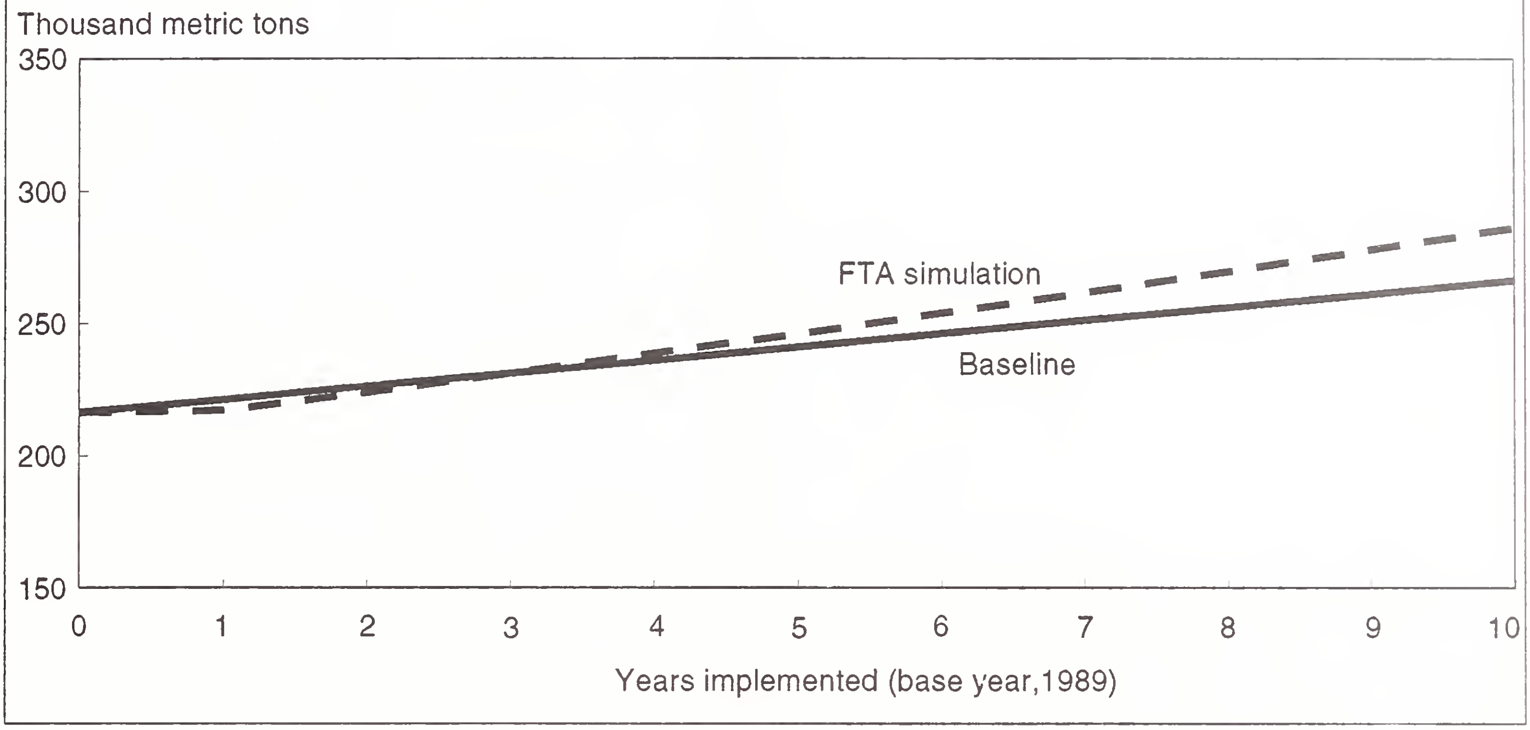
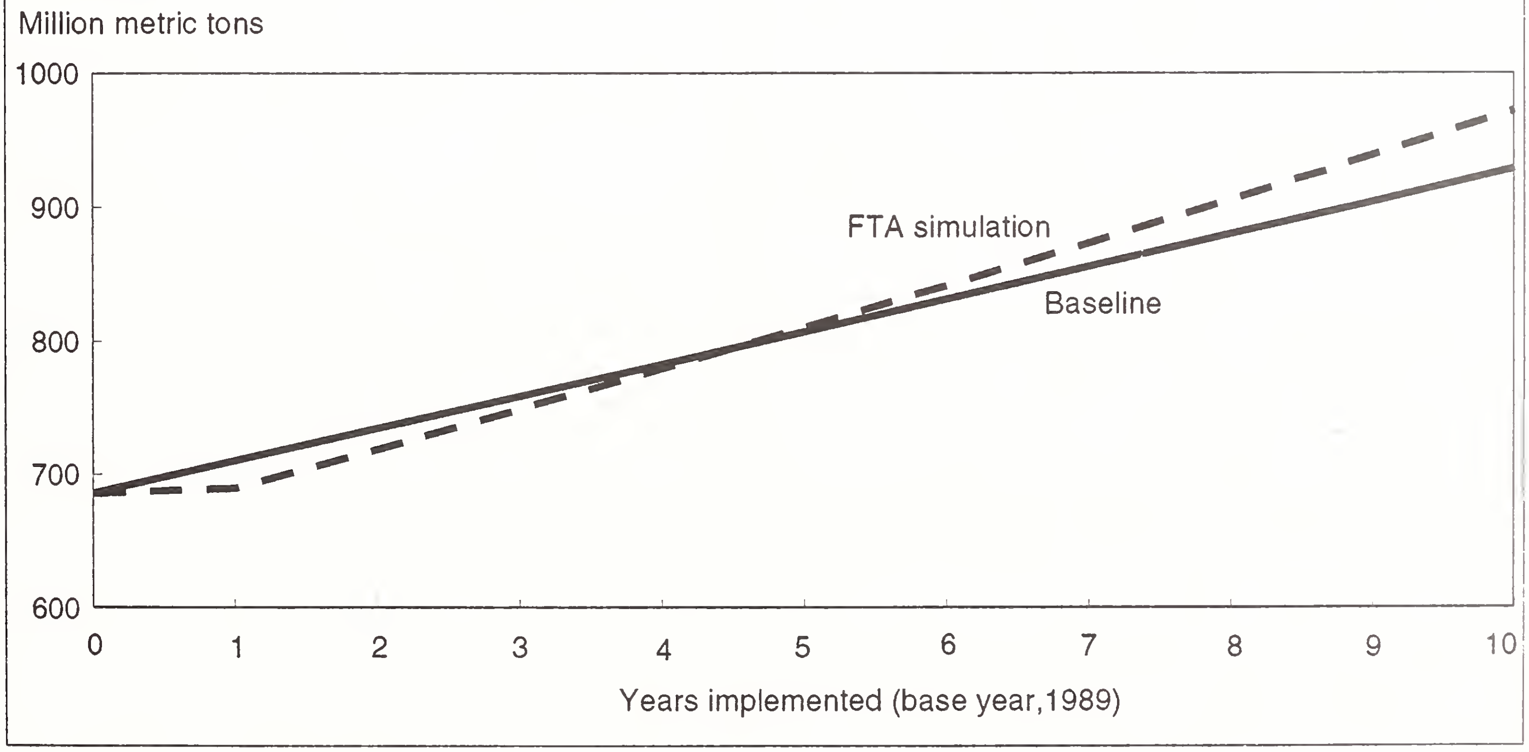


Figure 4
Canadian demand for U.S. vegetables



aggregate, or market, demand for vegetables would increase by approximately 7 percent while the Canadian market demand would increase by 12.7 percent over a baseline level with the tariff reductions. Tariff reduction simulations indicate that U.S. demand for Canadian vegetables will increase by 10.9 percent and Canadian demand for U.S. vegetables by 8.4 percent over the baseline. All of these percentage increases are credible given the existing levels of tariffs between the United States and Canada.

Several forces operate to increase and shift the patterns of international trade of fresh vegetables, including the increasing incomes in the Middle East and the U.S.-Canadian FTA. In addition, the NAFTA proposal would increase trade between the United States and Latin America, and a lowering of the CAP levy on U.S. vegetables would increase EC demand for this product.

References

Agriculture Canada. 1980. *Tariffs on Selected Agricultural Products.*

Alston, J., C. Carter, R. Green, and D. Pick. 1990. "Whither Armington Trade Models?" *American Journal of Agricultural Economics.* Vol. 72, No. 2.

Armington, P.S. 1969. "A Theory of Demand for Products Distinguished by Place of Production." *IMF Staff Papers.* Washington, DC: International Monetary Fund Vol. 16, pp. 159-77.

Artus, Jacques R., and Rudolf R. Rhomberg. 1973. "A Multilateral Exchange Rate Model." *IMF Staff Papers.* Washington, DC: International Monetary Fund. Vol. 20, pp. 591-611.

Bureau of Census. 1990. *U.S. Imports of Fresh Vegetables from Canada.*

Bureau of Census. 1990. *U.S. Imports of Fresh Vegetables from Mexico.*

Food and Agriculture Organization of the United Nations. 1962-1982. *FAO Production Yearbook.* Rome.

Goldstein, Morris, and Mohsin S. Khan. 1965. "The Supply and Demand for Exports: A Simultaneous Approach," *The Review of Economics and Statistics.* Vol. 32, pp. 275-85.

Hickman, Bert G., and Lawrence J. Lau. 1973. "Elasticities of Substitution and Export Demands in a World Trade Model," *European Economic Review.* Vol. 4, pp. 347-80.

Houthakker, H.S., and Stephen P. Magee. 1969. "Income and Price Elasticities in World Trade," *The Review of Economics and Statistics.* Vol. 51, pp. 111-25.

International Monetary Fund. 1984. International Financial Statistics tape. Bureau of Statistics of the International Monetary Fund. Washington, DC.

International Monetary Fund. 1989. *World Economic Outlook*, pp. 73-4. Washington, DC.

Lenouvel, Patrick. 1980. *Tariffs on Selected Agricultural Products.* Ottawa, Agriculture Canada, International Trade Policy Division.

Normile, Mary Anne, and Carol A. Goodloe. 1988. *U.S.-Canadian Agricultural and Trade Issues: Implications for the Bilateral Trade Agreement.* U.S. Dept. Agr., Econ. Res. Serv. Staff Report No. AGES880209.

Pindyck, Robert S., and Daniel L. Rubinfeld. 1981. *Econometric Models and Economic Forecasts.* New York: McGraw-Hill Book Company.

Sparks, Amy Larsen. 1987. "A Simultaneous Econometric Model of World Vegetable Trade: Implications for Market Development." Unpublished Ph.D. dissertation, University of Florida, Gainesville.

Theil, Henri. 1978. *Introduction to Econometrics.* Englewood Cliffs, NJ: Prentice-Hall, Inc.

United Nations. *Standard International Trade Classification (SITC)*, revised. 1961. Statistical Papers Series M, No. 32.

United States International Trade Commission. 1984. *Tariff Schedules of the U.S., Annotated, 1985.*

Winters, Alan L. 1984. *Developing Countries' Manufactured Exports: Some Simple Models.* Washington, DC: The World Bank.

Appendix—Derivation of the Product Demand Functional Form from the CRES Technical Relationship

CRES technical relationship:

$$X_{i.} = (\Sigma_j \beta_{ij} X_{ij}^{\alpha_{ij}})^{(1/\alpha_{i.})},$$

$$\partial X_{i.}/\partial X_{ij} = ((1/\alpha_{i.})((1/X_{ij}^{(1-\alpha_{ij})})(\alpha_{ij}\beta_{ij}X_{i.}^{(1-\alpha_{i.})}))).$$

The first-order conditions for optimum product mix in the i^{th} market imply:

$$P_{i.} = P_{ij}/(\partial X_i/\partial X_{ij}).$$

From this equation, derive the product demand equation (X_{ij}) as follows:

$$X_{ij} = ((P_{ij}/P_{i.})^{(1/\alpha_{ij}-1)} \; (\alpha_{i.}/\alpha_{ij}\beta_{ij}))^{(1/\alpha_{ij}-1)} \; (X_{i.}^{(\alpha_{i.}-1)/(\alpha_{ij}-1)}).$$

Macroeconomic Determinants of Relative Wheat Prices: Integrating the Short Run and Long Run

Mark Denbaly and David Torgerson

Abstract. *Prior empirical studies ignore that markets, subject to overshooting, determine farm prices and macroeconomic variables jointly. So, these elasticities are statistically unreliable. Using cointegration, with all variables determined simultaneously, we find that instantaneous wheat price elasticities with respect to the real exchange rate and interest rate are –1.27 and –1.97, respectively. Here, we measure the amount that the wheat price overshoots its equilibrium. The extent of overshooting differs for different monetary policy regimes. However, 57 percent of the deviation from longrun equilibrium is corrected within two quarters.*

Keywords. *Relative prices, real exchange rate, real rate of interest, cointegration, commodity prices, overshooting, and error-correction models.*

Over the past decade, analysts have determined that macroeconomic developments have important effects on the agricultural economy through relative farm-to-nonfarm prices. We will refer to such farm prices as relative farm prices. The magnitudes of the elasticities of relative farm prices, however, with respect to such key macroeconomic variables as the exchange rate and the interest rate, are still contested—for two substantive economic reasons.

First, theoretical work assessing the magnitude of the exchange-rate elasticity of the farm price has demonstrated that it is necessary to include all macroeconomic variables and treat them as endogenous in empirical models. This result occurs because the range of theoretically admissible values of the exchange-rate elasticity of commodity prices expands as more macroeconomic variables are treated as endogenous. In static single-market models with an exogenous exchange rate as the only macroeconomic variable, the theoretically derived elasticity of the commodity price with respect to the exchange rate is, inclusively, between –1 and 0. Orden (1986) shows, theoretically, that if the exchange rate and national income are included and treated as endogenous, this elasticity will not be restricted to values between –1 and 0.[1] With money demand depending on real income and a rapidly clearing money market, he shows that a change in the money stock induces a percentage change in the relative-farm-to-nontradeable-goods price, which may exceed the percentage change in the real exchange rate. Chambers and Just (1986) stress more general models and show that in theory the admissible exchange-rate elasticities of agricultural prices may be even less restricted if interest rates were also to be endogenized. They argue that making interest rates endogenous will allow a model to account for the dumping of grain stocks on world markets in response to tightening Federal Reserve policy. After the above discussions, it was clear that to estimate correctly the elasticity of a farm price with respect to a macroeconomic variable, all macroeconomic variables need to be included and treated as endogenous. However, the practical difficulty of estimating such a large econometric system has been overwhelming.

Second, to estimate properly the relative farm price elasticities with respect to macroeconomic variables, the dynamics of relative farm prices must be accounted for. This is because the magnitudes of these elasticities are affected by the atypical shortrun reaction of relative agricultural prices to changes in monetary policy. That is, in the short run, relative farm prices react to monetary policy by more than they do in the long run.

The atypical relative price dynamics is caused by what Dornbusch (1976) defined as overshooting. Overshooting is a more-than-proportionate shortrun response of a nominal asset price, such as a farm commodity price, to a change in money growth. The shortrun rigidity of manufacturing and service prices ensures this disproportionate response. Because of this general price rigidity, a change in nominal money supply affects the real money supply, which, in turn, influences the real interest and exchange rates in the short run by more than required in the long run. The endogenous shortrun reactions of real interest rates and exchange rates induce the more-than-proportionate reactions of flexible asset prices, such as farm commodity prices.[2] The specific

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[1]Sources are listed in the References section at the end of this article.

[2]Unlike prices for manufactured goods and services, the prices for farm commodities as well as financial assets are determined in auction markets and are thus highly flexible in the short run (Okun, 1981).

mechanisms by which monetary policy influences shortrun nominal farm price dynamics differs for open and closed economies. For example, in an open-economy model, a dynamic farm price adjustment is caused by the farm-export-demand effects of the real exchange rate response to a change in monetary policy (Stamoulis and Rausser, 1988). While, in a closed-economy model, a dynamic farm price adjustment is caused by crop-inventory-demand effects of the real interest rate response to a change in monetary policy (Frankel, 1986).[3]

Consequently, overshooting could substantially distort the relative farm prices in the short run, influencing the magnitudes of their elasticities with respect to macroeconomic variables. Thus, any attempt to measure the relative farm price elasticities must take into account the atypical relative farm price dynamics, which has not been done before.

The objective of this analysis is to estimate the macroeconomic elasticities of the relative wheat price, measuring the magnitudes of shortrun deviations from longrun equilibrium and the speed with which the relative price approaches its longrun equilibrium level. To this end, the relative wheat price is modeled using cointegration methodology that joins, in an econometrically acceptable manner, the longrun trend relationship between the relative price and its determinants, including macroeconomic variables, into a shortrun dynamic equation. The dynamic equation, referred to as an error-correction model, identifies how the rate of growth of the relative price responds to its shortrun deviations and to changes in the rates of growth of its longrun determinants. Thus, by accounting for the dynamics of price adjustments and treating all variables as endogenous, the new methodology resolves the two difficulties in estimating the elasticities of relative prices with respect to macroeconomic variables.

Cointegration and Error-Correction Models

Advances in cointegration by Engle and Granger (1987) and Johansen and Juselius (1990) provide the tools to apply dynamic error-correction models (ECM's), first suggested by Sargan (1964), that account explicitly for the dynamics of shortrun price adjustment toward longrun equilibrium. When variables in an equation are nonstationary, spurious regression results are likely, in which case correlated stochastic trends result in a high R^2, and nonstationary residuals produce a low Durbin-Watson statistic. The usual solution to achieving stationarity is to estimate the model in first differences. However, this first-differencing typically results in a loss of information concerning the long-term relationship between the variables.

Cointegration analysis resolves this problem by identifying conditions under which a relationship is robust (Engle and Granger, 1987). If variables are cointegrated, longrun trends (secular components) of time series variables adjust in accordance with an equilibrium constraint, and the shortrun dynamics (cyclical components) conform to the class of ECM's. That is, while stochastic trends cause the variables to wander apparently randomly, the time series variables eventually follow one another if they are cointegrated. In this way, cointegration and error-correction modeling reintroduce, in a statistically acceptable way, the longrun information omitted from the differenced models.

Consider the simple case of two endogenous time-series variables, x_t and z_t, with single-unit roots whose first differences are stationary.[4] The linear combination, referred to as the cointegrating equation:

$$w_t = x_t - a - bz_t, \qquad (1)$$

is generally I(1), where a and b are constants. However, if there exists an a and b such that w_t is level stationary, I(0), then x_t and z_t are said to be cointegrated, and the relationship:

$$x_t - a - bz_t = 0, \qquad (2)$$

is the cointegrating or equilibrium relationship with w_t representing the equilibrium error. When cointegrated, the shortrun dynamic processes through which the series adjust toward their longrun equilibria are represented by constrained ECM's. The ECM's specify that the first differences of x_t and z_t are functions of distributed lags of first differences of both variables as well as the once-lagged equilibrium error, w_{t-1}, referred to as the error-correction term (ECT). Because the series are

[3]Although the overshooting literature emphasizes the implications of nominal price dynamics, "...the importance ... is not the overshooting result *per se* but the possibility that relative prices of farm products can be affected by monetary policy" (Stamoulis and Rausser, 1988, p. 185). Agricultural production and real farm income are strongly influenced by relative farm prices. Monetary policy, via commodity overshooting, affects relative farm prices. Thus, in the short run, monetary policy influences real farm income and agricultural production. Tight monetary policy is an implicit tax on farm production and farm income.

[4]A variable is integrated of order d, I(d), if its dth difference is a stationary, invertible, nondeterministic ARMA process. A variable integrated of degree zero is therefore stationary in its level.

cointegrated, the ECT is stationary, matching the I(0) first differences. Hence, the least squares standard errors of the ECM, using the ordinary least squares residuals of equation 1 in place of the ECT, will be consistent estimates of the true standard errors (Engle and Granger, 1987, p. 262).

In the bivariate case, the cointegrating vector, [1, –b], must be unique since any other parameter, say (b+c), introduces the additional nonstationary term, cz_t. When more than two variables are involved, the cointegrating vector may not be unique. Engle and Granger's two-step procedure assumes a unique cointegrating vector. So, their cointegration test does not distinguish between the existence of one or more cointegrating vectors. Johansen and Juselius (1990) provide a maximum likelihood procedure to estimate the parameters of and to test for the number of cointegrating vectors.

The modeling of macroeconomic and relative farm price variables is a natural application of cointegration, since the overshooting literature demonstrates that relative agricultural prices exhibit shortrun departures from longrun equilibrium. Cointegration analysis determines the longrun relationships between the observed values of the relative wheat price and the other time series involved, where the residuals measure the extent of disequilibria. And, the ECM describes the shortrun dynamic adjustment of the relative wheat price.

Empirical Results

The solution to a typical static general equilibrium model specifies that the relative wheat price, P, depends on the real exchange rate, Q, real domestic income, Y, real foreign income, Y*, real interest rate, R, and the wheat stocks carried over from the last period, S (see app. I). Assuming a log-linear function, the relative wheat price model is:

$$lnP = k + alnQ + blnY + clnY^* + dlnR + elnS, \quad (3)$$

where k, a, b, c, d, and e are constant parameters.

Cointegration and error-correction modeling involves three steps. First, the order of integration for each variable is determined. If a series is nonstationary, it will be successively differenced until stationarity is obtained. Second, if nonstationary variables are integrated of the same order, a linear combination of them can be stationary. The Johansen-Juselius procedure tests for cointegration, identifying the number of cointegrating vectors. Finally, if the cointegrating vector is unique, the OLS residuals from equation 3 can be used to measure the equilibrium error, ECT, to proceed with the estimation of the dynamic ECM.

Data

The data are quarterly and cover the 1977.4-1989.4 period. The relative wheat price is measured by the ratio of the seasonally adjusted (fourth difference) wheat (Chicago no. 2 soft red winter) price to the Nonfood Consumer Price Index. The real exchange rate is a wheat-trade-weighted index of the real value of the U.S. dollar. U.S. disposable personal income (constant 1982 dollars) represents the real domestic income. The index of OECD's quarterly industrial production is a proxy for income of major U.S. wheat importers—a series which is not available. The real interest rate is calculated by subtracting the rate of inflation (measured using the Consumer Price Index) over a quarter from the prime rate at the beginning of the quarter. Beginning stocks are the deseasonalized total wheat inventory measured over noncalendar quarters, for example, December-February. Because deseasonalizing prices and inventories removed the overall mean, all other series were also expressed as deviations from their means.

Integrating Properties of the Variables

Unit-root test procedures developed by Fuller (1976) and Dickey and Fuller (1981) are applied to examine the orders of integration. The procedure starts with the following regression:

$$\Delta z_t = \alpha + \beta t + (\rho-1) z_{t-1} + \sum_{i=1}^{m} \rho_i \, \Delta z_{t-i} + e_t, \quad (4)$$

where z is the variable under consideration, Δz_{t-i} is the first difference at time t–i, and m is the number of lags that ensures adequate representation of the time series z, that is, when the error term, e_t, is white noise. The null hypothesis for a unit root requires that ρ=1, in which case the variable z is said to be nonstationary. The statistic used for the test, named τ_τ, is the usual t-statistic calculated under the hypothesized null. However, the τ_τ statistic is not distributed as the standard t. Fuller provides the critical values for the τ_τ distribution.

If a unit root is detected, it is possible that a second unit root exists as equation 4 has m characteristic roots. In this case, application of the same procedure to the first difference of a variable tests for possible existence of a second unit root. Because the variable of interest is the first

difference of z, model (4) without the deterministic time trend and drift is estimated. Once again, the statistic used for the test, named τ, is the usual t-statistic calculated under the hypothesized null whose critical values are reported in Fuller. If a second unit root is found, the procedure will be continued until the order of integration, that is, the appropriate number of differencing to achieve stationarity, is identified.

To determine the order of autoregression, m, the Akaike (1977) information criterion was applied, which indicated that variables in equation 3 are generated by AR(1) processes.[5] Other tests for additional lag terms indicated that AR(1) was sufficient to represent these processes.[6]

The outcome of the tests are similar for all series (table 1). The null hypothesis of a unit root could not be rejected at the 10-percent significance level. The results using first-differenced data unanimously rejected the hypothesis of second-unit roots. So, each series is characterized as a nonstationary I(1) process.

Cointegration Test

Because all variables are I(1), one or more linear combinations of these series could be stable in the long run if they are cointegrated. To test for cointegration, the Johansen-Juselius maximum likelihood procedure is applied. The procedure involves the identification of rank of the matrix Π in:

$$X_t = \varphi + \sum_{i=1}^{k} \Pi_i X_{t-i} + e_t, \qquad (5)$$

where X_t is a column vector made up of p (here six) series involved in the analysis. The procedure is based on the error-correction version of equation 5:[7]

$$\Delta X_t = \varphi + \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + \Pi X_{t-k} + e_t, \qquad (6)$$

where $\Gamma_i = -[I - \Pi_1 - \ldots - \Pi_i]$ for i = 1,...,k–1; and, $\Pi = -[I - \Pi_1 - \ldots - \Pi_k]$. Johansen and Juselius show that if the rank is zero, the variables are not cointegrated. However, if the rank is r, there exist r possible independent stationary linear combinations. In the latter case, equation 6 represents an ECM described by Engle and Granger.

The tests to determine the rank of Π involve the estimates of the ordered eigenvalues, $\lambda_1 > \ldots > \lambda_p$, from the characteristic equation:

$$|\lambda S_{kk} - S_{ko}(S_{oo})^{-1} S_{ok}| = 0,$$

where $S_{ij} = T^{-1} \sum_{t=1}^{T} R_{it} R_{jt}'$ for i, j = 0,k, and T is the sample size. The R_{ot} and R_{kt} are the OLS residuals obtained by regressing ΔX_t and X_{t-k} on an intercept and $\Delta X_{t-1}, \ldots, \Delta X_{t-k+1}$, respectively. First, test that the rank of Π is less than or equal to one, that is, H_o: $r \leqslant 1$. The likelihood ratio statistic, called the trace, is given by:

$$-2ln(Q) = -T \sum_{i=2}^{p} ln(1-\lambda_i).$$

If the null hypothesis is not rejected, the hypothesis that the rank of Π is zero should be tested, or H_o: r = 0. The trace statistic for this test is:

$$-2ln(Q) = -T \sum_{i=1}^{p} ln(1-\lambda_i).$$

If the null is not rejected, then the rank is zero and the series are not cointegrated. Otherwise, one would conclude that a unique cointegrating vector exists.

An additional statistic, called the maximal eigenvalue statistic, provides evidence that should confirm the inference obtained by the trace statistics. For example, given that $r \leqslant 1$, the maximal statistic for the null hypothesis that the rank is zero is:

$$-2ln(Q;\ r=0|r\leqslant 1) = -T\ ln(1-\lambda_1).$$

Table 1—Unit-root tests, I(1) and I(2)

Variable[1]	Levels, H_o: I(1)[2]	Differences, H_o: I(2)[3]
Relative wheat price	–1.92	–5.13
Real exchange rate	–1.94	–5.18
U.S. disposable income	–1.42	–4.68
OECD industrial production	–1.76	–4.55
Real interest rate	–1.67	–6.90
Wheat inventory	–2.76	–7.44

[1]All variables are in logarithm.
[2]Critical values τ_τ for n = 50 are –3.18 and –4.15 at 10- and 1-percent significance levels, respectively.
[3]Critical values of τ for n = 50 are –1.61 and –2.66 at 10- and 1-percent significance levels, respectively.

[5]These findings are also consistent with behaviors of autocorrelation and partial autocorrelation functions of the variables.

[6]The test is based on Fuller's proof (1976, chap. 8) that while the limit distributions of OLS estimators of α, β, and ρ are not normal, the distribution of such estimators for ρ_i's converge in the limit to a multivariate normal. Consequently, an ordinary t-test can be used to test for the possible existence of an additional lag.

[7]Equation 6 is derived from equation 5. Any autoregressive time series of order k can be written in terms of its first difference, its level lagged k times, and k–1 first differences (Dickey and others, 1991).

Similarly, if the trace statistics cannot reject the hypothesis that $r \leq 2$, then the result that $r=1$ can be confirmed by the maximal statistic:

$$-2ln(Q;\ r=1|r\leq 2) = -\ T\ ln(1-\lambda_2).$$

The distributions of these statistics are not the usual chi-square. Johansen and Juselius provide the asymptotic critical values.

The lag structure of equation 6 must be determined to conduct the test. One lag proved to be sufficient using the Akaike information criterion. The trace statistic for the null hypothesis that $r \leq 1$ was 62.4, indicating that the hypothesis of at most one cointegrating vector cannot be rejected at the 10-percent significance level. Because the dimensions of the distribution tables in Johansen and Juselius are limited to five series, the trace and maximal tests for $r = 0$ could not be performed. Instead, the trace test was used for the hypothesis that $r \leq 2$. At 34.64, the null could not be rejected at the 20-percent level. Having accepted this null, we used the maximal statistic to test that $r = 1$ against the alternative that $r = 2$. At 21.84, the statistic could not, at the 50-percent significance level, reject the null that there exists a unique cointegrating vector.

Error-Correction Model

Engle and Granger proved that cointegration implies an ECM. Since the variables in equation 3 are cointegrated, the shortrun dynamics of the relative wheat price follows an ECM that relates its growth rate to its past deviations from longrun equilibrium, that is, the ECT, and to the growth rates of the other variables (see appendix II). Uniqueness of the cointegrating vector means that the estimated residual of the cointegrating equation represents the equilibrium error.

A major decision is the choice of lag length. Because of the complexity of dynamic relationships, the orders of autoregressive-distributed lag (ADL) structure of ECM's may be complicated (Engle and Granger, 1987).[8] To find the lag lengths, Hendry's general-to-specific modeling strategy is followed, which estimates an unrestricted ADL version of the model first and, then, simplifies the representation by eliminating the lags with insignificant parameters.[9] Since the data are quarterly, four lags of each variable were included initially. However, because of high correlation (0.95) between the logarithms of U.S. disposable personal income, y, and OECD industrial production, y*, the X matrix was singular. Only current y* could be included for the matrix to be invertible. In addition, lags 2-4 were insignificant for all other variables. Subsequently, the analysis of lag structure was performed for four lags of y, current y*, and one lag of all other series. Based on these results and tests on the significance of each variable and each lag, the basic model was obtained by eliminating y*, the lagged dependent variable, all but lags 3 and 4 of y, the first lag of the ECT, and the constant term.

The final stage is to transform the basic equation such that all variables are I(0), and so that the standard inference procedure applies to all tests. As Hendry (1989) points out, doing so results in a nearly orthogonalized specification of the ADL. The earlier unit root tests established that all time series are AR(1), so that their first differences are I(0) (table 2).

All estimated coefficients are statistically significant and have the expected theoretical signs (see appendices I and II). A battery of tests are used to validate the model. As far as the residuals go, the DW statistic provides no evidence of serial autocorrelation, the LM test supports a white noise process, and the Jarque-Bera test indicates an approximately normal distribution. The RESET and White tests provide no evidence of heteroscedastic misspecification.[10]

Table 2—The error-correction model

Variable	Coefficient	Standard error	t-value
Δq	−1.27	0.407	−3.11
Δy_{t-3}	1.70	.863	1.97
Δr	−1.97	.593	−3.33
Δs	−.32	.075	−4.22
ECT_{t-2}	−.57	.088	−6.39

R^2 = .62 σ = .066 F(5, 44) = 14.52 DW = 2.32
Jarque-Bera test of normality: $Chi^2(2)$ = 1.37
LM test of 4th order autoregressive errors: F[4, 40] = 1.59
White's test of heteroscedastic errors: F[10, 33] = .68
RESET specification test: F[1, 43] = 2.22

The dependent variable is Δp. Δ is the first difference operator. p, q, y, r, and s are the logarithms of the relative wheat price, real exchange rate, U.S. disposable income, real interest rate, and beginning inventory, respectively. The sample period is 1977.4-1989.4.

[8]In a money demand study, Hendry and Ericsson (1991), for example, estimated an ECM which includes nonlinear ECT's, first differences, second differences of lagged levels, and the rate of growth over the past two periods.

[9]Hendry's software package, PC-GIVE, is used to estimate the ECM.

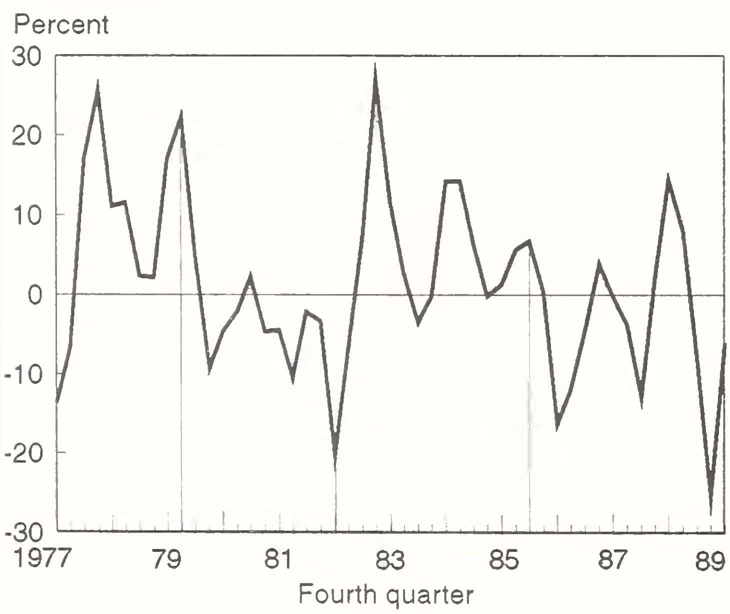
[10]An extensive battery of parameter constancy tests using recursive estimation for the out-of-sample period 1983.3-1989.4 is also conducted. Chow tests, recursively estimated parameter values, and residuals along with their standard errors strongly suggest that the parameters are constant. The results are available on request.

The estimated ECM quantifies the effects of macroeconomic shocks characterized as significant upon relative agricultural prices (for example, Rausser and others, 1986). Consistent with Orden's theoretical result, the elasticity of the relative wheat price with respect to the real exchange rate exceeds unity. The significant negative price influence of real appreciation of the dollar through its effect on the wheat export demand is even more profound if the exchange rate itself overshoots its equilibrium in response to a monetary shock.

The relative wheat price is even more elastic with respect to the real interest rate. The statistical significance and magnitude of the elasticity confirm the theoretical expectation that interest rate movements have important negative effects on current commodity prices via their influence on the demand for inventory (for example, Frankel (1986), Chambers and Just (1986), and Gardner (1979)).

While the coefficients indicate large immediate responses to changes in the dollar's value and the interest rate, the negative coefficient of the ECT ensures, consistent with overshooting, that longrun equilibrium is achieved. The adjustment toward equilibrium is not instantaneous, however. Fifty-seven percent of any quarter's deviation from equilibrium is incorporated into the next two quarters' growth rate of the relative wheat price. The direction of departures from equilibrium reported (fig. 1) is also consistent with the conclusions of the overshooting analysis (for example, Stamoulis and Rausser, 1988). During the accommodative monetary policy of the late 1970's the relative wheat price was usually above its equilibrium. During the tight monetary policy and high budget deficits of the early 1980's, the relative wheat price was usually below its equilibrium values. When the Federal Reserve began to ease monetary policy in the fourth quarter of 1982, the relative wheat price rose above its equilibrium level. The Federal Reserve pursued a relatively tight monetary policy between 1986 and 1989, and the relative wheat price was below its equilibrium for much of that period.

Figure 1
Relative wheat price departure from equilibrium



Over the sample period, the magnitude of the deviation from equilibrium has been large at times, reaching 28 percent in absolute value. The relevant policy question is: Should there be an agricultural policy response to such large shortrun relative price departures? The present analysis does not provide a clear-cut answer to this question. As our analysis demonstrates, 57 percent of any shortrun departure is corrected for in the following two periods. If a monetary shock, for example, is temporary, then no agricultural policy action is called for. Just and Rausser (1984) have discussed, however, alternative agricultural public policy options for situations under which continued adverse macroeconomic conditions cause relative farm prices to fall below their longrun equilibrium for extended periods of time.

Conclusions

There is no question that macroeconomic developments alter the economic well-being of farmers. The theory tells us that changes in macroeconomic policy produce real economic consequences for the agricultural sector through generating an atypical relative farm price dynamic. The theory also tells us that the relative farm price impact, for example, is carried through the real exchange rate and the real interest rate. In particular, because of the general price level rigidity, the relative farm price overshoots its longrun equilibrium level in the short run.

But, how significant are the macroeconomic effects? No one knew. Any empirical assessment of the above theory depends on the ability to join the shortrun and the longrun dynamics to measure the size and duration of the relative-price overshooting, as well as to estimate the macroeconomic elasticities of relative farm prices. If the deviations from longrun equilibrium are small, the economic effects will be insignificant no matter how long the duration. If the size of the overshooting is large, then the economic effects will be significant, especially if the duration is long. Here, the

significance of these macroeconomic impacts for the wheat market is measured. The largest overshooting happened in 1983:3 when the relative wheat price overshot its equilibrium by 28 percent during a period of accommodative monetary policy. Almost 60 percent of a departure from equilibrium in any quarter is incorporated into the growth rate of the relative wheat price in the following two quarters.

Our empirical study reveals the extent by which monetary policy can affect the relative wheat price in the short run, particularly through its effect on the real exchange rate and the real interest rate. During the periods of expansionary monetary policy, the wheat price rises relative to its equilibrium level. Specifically, the relative wheat price immediately increases by 1.27 percent to a 1-percent depreciation in the real value of the dollar and by 1.97 percent to a 1-percent decline in the real interest rate. This means that expansionary monetary policy disproportionately benefits wheat producers, relative to noncommodity sectors, in the short run as relative wheat prices overshoot and real interest rates decline. Conversely, tight monetary policy hurts wheat producers in the short run.

References

Akaike, H. 1977. "On Entropy Maximization Principle," *Applications of Statistics*. P.R. Kirshniah (ed.). Amsterdam: North Holland.

Chambers, R.G., and R.E. Just. 1986. "A Critique of Exchange Rate Treatment in Agricultural Trade Models: Reply," *American Journal of Agricultural Economics*. Vol. 68, pp. 994-97.

Dickey, D.A., D.W. Jansen, and D.L. Thornton. 1991. "A Primer on Cointegration with an Application to Money and Income," *Federal Reserve Bank of St. Louis Review*. Vol. 73, pp. 58-78.

Dickey, D.A., and W.A. Fuller. 1981. "Likelihood Ratio Statistics for Autoregressive Time Series with Unit Roots," *Econometrica*. Vol. 49, pp. 1,057-72.

Dornbusch, R. 1985. "Purchasing Power Parity." Working Paper No. 1591. National Bureau of Economic Research, Cambridge, MA.

Dornbusch, R. 1976. "Expectations and Exchange Rate Dynamics," *Journal of Political Economy*. Vol. 84, pp. 1,161-76.

Engle, R., and C. Granger. 1987. "Co-Integration and Error Correction: Representation, Estimation, and Testing," *Econometrica*. Vol. 55, pp. 251-76.

Frankel, J.A. 1986. "Expectations and Commodity Price Dynamic: The Overshooting Model," *American Journal of Agricultural Economics*, pp. 344-48.

Fuller, W.A. 1976. *Introduction to Statistical Time Series*. New York: John Wiley.

Gardner, B.L. 1979. *Optimal Stockpiling of Grain*. Boston: Lexington Books.

Hendry, D., and N. Ericsson. 1991. "An Econometric Analysis of U.K. Money Demand in Monetary Trends in the United States and the United Kingdom, by Freidman and Schwartz," *American Economics Review*. Vol. 81, pp. 8-38.

Hendry, D. 1989. *PC-GIVE: An Interactive Econometric Modelling System*. Institute of Economics and Statistics and Nuffield College, University of Oxford.

Johansen, S., and K. Juselius. 1990. "Maximum Likelihood Estimation and Inference on Cointegration—with Application to the Demand for Money," *Oxford Bulletin of Economics and Statistics*. Vol. 52, pp. 169-210.

Just, R.E., and G.C. Rausser. 1984. "Uncertain Economic Environments and Conditional Policies," *Alternative Agricultural and Food Policies and the 1985 Farm Bill*. Rausser and Farrell (eds.). Berkeley, CA: Giannini Foundation.

Okun, A.M. 1981. *Prices and Quantities*. Washington: Brookings Institution.

Orden, D. 1986. "A Critique of Exchange Rate Treatment in Agricultural Trade Models: Comment," *American Journal of Agricultural Economics*. Vol. 68, pp. 990-93.

Rausser, G.C., J.A. Chalfant, H.A. Love, and K.G. Stamoulis. 1986. "Macroeconomic Linkages, Taxes, and Subsidies in Agricultural Sector," *American Journal of Agricultural Economics*. Vol. 68, pp. 339-417.

Sargan, J.D. 1964. "Wages and Prices in the United Kingdom: A Study in Econometric Methodology," *Econometric Analysis for National Economic Planning*. Harts, Mills, and Whitaker (eds.). London: Butterworth, pp. 22-54.

Stamoulis, K.G., and G.C. Rausser. 1988. "Overshooting of Agricultural Prices," *Macroeconomics, Agriculture, and Exchange Rates*. Paarlberg and Chambers (eds.). Boulder, CO: Westview Press, pp. 163-88.

Appendix I—The Canonical Static Model

Consider an economy that consumes two distinct types of goods: tradeable commodities, which are internationally arbitraged, and nontradeable goods

with sticky prices. Excluding information or transportation costs and assuming no trade barriers, the law of one price (LOP) applies to commodities at any time. Under such conditions, the real exchange rate, defined as the deviation from purchasing power parity, is determined by the relative international price of nontradeables (Dornbusch, 1985). Stated in real terms, the LOP can be expressed as:

$$\left(\frac{PC^*}{PN^*}\right) = \left(\frac{E \times PN}{PN^*}\right)\left(\frac{PC}{PN}\right), \tag{A1}$$

where "*" denotes foreign variables, PC and PN are the domestic currency prices of the commodities and nontradeables, respectively, and E is defined as the domestic currency price in world money. Denoting the real exchange rate with "Q," and domestic and foreign relative commodity prices with "P" and "P*," respectively, the equilibrium condition (A1) is restated as:

$$P^* = Q \times P. \tag{A1.1}$$

Let export demand, X, be represented with the following function:

$$X = x(PC^*, PN^*, YN^*);$$

$$\frac{\partial X}{\partial PC^*}<0, \frac{\partial X}{\partial PN^*} \text{ and } \frac{\partial X}{\partial YN^*}>0, \tag{A2}$$

where YN* is nominal foreign income. The function x is homogeneous of degree zero in nominal prices and income. So, (A2) can be rewritten as:

$$X = x(P^*, Y^*); \frac{\partial X}{\partial P^*} <0 \text{ and } \frac{\partial X}{\partial Y^*} >0, \tag{A2.1}$$

where Y*=(YN*/PN*) is real foreign income and P*=(PC*/PN*). Substituting from (A1.1) into (A2.1), we have:

$$X = x(Q \times P, Y^*). \tag{A2.2}$$

Similarly, domestic demand, D, is given by:

$$D = d(P, Y); \frac{\partial D}{\partial P} <0 \text{ and } \frac{\partial D}{\partial Y} >0, \tag{A3}$$

where Y is real domestic income, and, as before, P is the domestic price of tradeable commodities relative to nontradeable goods.

Finally, allow the inventory demand, I, to be described by:

$$I = i(R); \frac{\partial I}{\partial R}<0, \tag{A4}$$

where R is real rate of interest.

Given this structure, relative price is determined by the equilibrium condition that markets clear in the short run. Because agriculture is the focus of this analysis, in the short run, that is from quarter to quarter or month to month, expected production is assumed constant. Therefore, intrayear supply for a given period is the total stocks carried over from the last period. That is,

$$X + D + I = S, \tag{A5}$$

where S is the predetermined current supply.

Now, substituting for X, D, I from (A2.2), (A3), and (A4) into (A5) and solving for domestic relative price yields:

$$P = f(Q, Y, Y^*, R, S), \tag{A6}$$

where P is the equilibrium level of current relative price. Comparative statics show readily that, given the assumptions made so far about the signs of the partial derivatives, we must *a priori* expect to have:

$$\frac{dP}{dQ} <0, \frac{dP}{dY^*}>0, \frac{dP}{dY} >0, \frac{dP}{dR} <0, \text{ and } \frac{dP}{dS} <0.$$

Appendix II—Shortrun Dynamics of an Error-Correction Model

The first discussion of ECM's appeared in Sargan (1964), before Engle and Granger developed the concept of cointegration. ECM's are built around the notion that available data summarize the forces involved in a dynamic process of convergence toward longrun equilibrium values. As Engle and Granger show, if an I(1) vector of economic variables is generated by an ECM, the series must necessarily be cointegrated. In other words, as in the context of cointegration, ECM's define longrun equilibrium as a stationary linear relationship similar to equation 2. However, Sargan motivated ECM's by defining longrun equilibrium as in the steady state. In the context of our price model, equation A6, the steady-state equilibrium would be:

$$P = K\, Q^a\, Y^b\, Y^{*c}\, R^d\, S^e. \tag{A7}$$

Equation A7, which represents the stable longrun relationship, is linear in the logarithms of the variables, that is:

$$\mathrm{p} = \nu_I + z\nu, \tag{A8}$$

where p is the logarithm of relative wheat price, ν_I is the logarithm of the intercept K in equation A7, z is the logarithm of the row vector containing the

determinants of relative wheat price, and ν is the column vector [a, b, c, d, e,]'. To allow convergence to longrun equilibrium, some sort of shortrun dynamics is needed. To illustrate the mechanics of convergence, assume the simplest case of an AR(1) type process:

$$p_t = \alpha p_{t-1} + \mu + z_t\theta + \xi, \tag{A9}$$

where $|\alpha| < 1$, μ is the intercept, θ is a column vector of shortrun price elasticities, and ξ is a serially uncorrelated error term with a constant variance and zero mean.

Given the shortrun dynamic model A9, the steady-state solution can be obtained when longrun equilibrium is defined as a dynamic steady state, in which all equilibrium values grow at a constant rate. To see this, rearrange A9 by subtracting p_{t-1} from both sides, and adding and subtracting $z_{t-1}\theta$ from the right-hand side to obtain:

$$g_p = \mu + g_z\theta + (\alpha-1)\,[p_{t-1} - z_{t-1}(1-\alpha)^{-1}\theta] + \xi, \tag{A10}$$

where g_p is the growth rate of the relative wheat price, and g_z is the row vector of growth rates of the variables in z. The term inside the brackets in equation A10 provides the error-correction mechanism. If the demand, p, rises above its longrun equilibrium level at time t–1, the term in the brackets becomes positive. However, because $(\alpha-1)$ is negative, its effect at time t is to reduce the growth rate of the observed p toward its steady-state path. For this reason, equation A10 is referred to as an error-correction model.

Perspective on Farm Size and Structure Provided by Value-Added Measures

B.F. Stanton, John E. Jinkins, Mary C. Ahearn, and Gregory D. Hanson

Abstract. *Much wider use of net value-added, instead of gross sales, can lend perspective on how farm size and structure are changing in the United States. Net value-added is a more appropriate economic measure to use in comparing farms by size or type on a consistent basis. Net value-added emphasizes the net returns to farm households from the use of their land, labor, capital, and management in agricultural production. Net value-added as a percentage of gross farm income is highest (over 60 percent) on vegetable, greenhouse and nursery, and cash grain farms. It is much lower on livestock farms that buy substantial amounts of their inputs (fed cattle and hogs). Wider use of net value-added directs attention to the economic impact of resources used in agricultural production in the form of returns to those resources.*

Keywords. *Net value-added, size distribution, farm structure.*

Structural change in American agriculture, including the number and size distribution of farms, has prompted policy discussions on the implications of the continued concentration of production. For example, policymakers recently debated a proposal to limit direct Government payments to producers based on some maximum level of farm size. This proposal would have implied a limitation on the receipt of payments in addition to the existing $50,000-per-person limit. The motivation behind the targeting of Government payments is often the preservation of family farms, that is, small and midsized farms. The Small or Limited Resource Farmers' Initiative, administered by USDA's Farmers Home Administration, bases eligibility for loan assistance, in part, on farm size.

The most common measure of farm size is gross sales. USDA has for some time tracked such characteristics as the distribution of income and wealth, and land tenure by gross sales classes. For example, the first U.S. net farm income estimates by the value of agricultural product classes were published in 1944 (USDA, 1988).[1] USDA now maintains an annual series of farm income, assets, and debt by gross sales classes beginning with the year 1960 (USDA, 1991). However, gross sales as an indicator of farm size do not consider inventory adjustments or Government payments. Gross sales from farms that produce their final product from large quantities of agricultural commodities used as intermediate goods, like fed cattle operations, overstate the farms' size and importance in the sector (Hanson, Stanton, and Ahearn, 1989).

Net value-added is another measurement of farm size and more appropriate to making relevant comparisons across different types of farming. Net value-added measures the share of net output that remains in the farm sector to reward all persons who have committed land, labor, capital, or management skills to these businesses.

The purpose of this article is to show how net value-added can be measured for individual farms to provide a more effective way of looking at the structure of agriculture. Systematic study of distributions of net value-added for individual farms can help the public appreciate more fully which types and sizes of farms are most important in adding to net agricultural output and why gross sales may give misleading impressions when studying structural change.

Value-Added Accounts in an International Setting

Value-added estimates are frequently included in the aggregate national income and product accounts of many countries, including the United States (U.S. Dept. Commerce, 1985). A standard set of economic accounts for agriculture has been established for the 23 participating countries in the Organization for Economic Cooperation and Development (OECD). Final agricultural output, gross value-added at market prices and at factor cost, net value-added, net operating surplus, and net income from agriculture are determined annually for each country (OECD, 1991). The defini-

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[1]Sources are listed in the References section at the end of this article.

tions and methodology used rely heavily on the original concepts established by the Statistical Office of the United Nations and the modifications and experience of the 12 member countries of the European Community (EC) in harmonizing their national accounts into one comprehensive system. Estimates of net value-added at factor cost are available for the United States and nearly all other countries from 1974 on. Hayami and Yamada (1991), using this basic methodology, have estimated annual compound rates of growth for both gross and net value-added from agriculture in Japan for 1880-1985.

Value-added measures are less common for individual firms. However, they are beginning to appear in the annual statements of a few U.S. corporations as a part of what Meek and Gray (1988) termed "corporate social responsibility disclosure." A number of industrial corporations in Britain have published such estimates since the late 1970's (McLeay, 1983; Morley, 1979). Value-added for individual farms has been estimated in Canada (Brinkman, 1989), the United Kingdom (Murphy, 1989; Outlaw and Croft, 1982), and the EC (Farm Accounting Data Network, 1986). While details of estimation differ modestly, "value-added can be conceptually recognized as the residual after deduction of exhaustible inputs; that is to say purchased materials used up in the production process, depreciation charges (capital consumption), and as far as accounting procedures will allow, other purchased items such as energy and repairs to machinery" (Murphy, 1989). In some analytic work, net value-added is distributed finally to farm employees, landowners, lending agencies, and the farm operator-manager (Jinkins and Ahearn, 1991).

Database for Analysis

Individual farm records from the 1989 Farm Costs and Returns Survey (FCRS) provided the basic data for this study. The FCRS has been conducted annually since 1984 by USDA. The 11,836 farmers interviewed for the 1989 survey statistically represented 1.7 million farms. Substantial experimentation and analysis on value-added calculations were also completed using FCRS data for 1986-88.

We do not include an estimate for the depreciation expense incurred by landlords and contractors because it is not available from our data source. The FCRS is a survey of farm operators. Operators of farm businesses are asked to provide estimates of expenses paid by contractors and landlords. Operators will generally not be able to provide reliable estimates of depreciation for landlords and contractors. The effect of excluding landlord and contractor depreciation is to overstate net value-added by the amount of that depreciation.

Issues in Defining Value-Added for Individual Farms

Although the value-added concept is basic and widely recognized by economists, variations exist in the details of measurement.[2] If value-added is being calculated for all industries in the economy, the accounting must adhere to strict rules that avoid double-counting. We are interested only in a single industry, agriculture, however, so we have made modifications to standard national income conventions.

Our specific accounting for value-added is as follows:

Gross income	*Deductions*
Commodity sales of operation	All production expenses except:
Changes in inventory	Wages and related expenses
Government payments	Taxes
Value of home consumption of farm products	Interest
Farm-related income	Rent (cash and share)
Value of commodities produced under production contracts	
Value of share rents	

Gross farm income − Total deductions = Net value-added

Accounting for Value-Added

For much of agriculture, government payments and programs are not a major issue. Prices and production for fruits, vegetables, hay, soybeans, many field crops, and all livestock except dairy are determined primarily in the marketplace. That is not the case for food and feed grains, peanuts, cotton, tobacco, sugar, and dairy products. Controls on production and imports of peanuts and sugar, for example, insure farm prices well above those in international markets. In contrast, direct payments are made to producers who participate in government programs that require reductions in acreage.

We include direct government payments as a source of gross income because these payments are

[2]"The value-added by a firm is its revenue from selling a product minus the amounts paid for goods and services purchased from other firms, or value-added = wages + interest + rents + taxes paid + profit" (Baumol and Blinder, 1979).

a component of market prices that would have occurred if government intervention were not so prevalent worldwide. Part of the payments can be regarded as rent for acres idled in commodity programs. The standard procedure used by OECD countries in their economic accounts for agriculture is to add "subsidies" to gross value-added (market prices) and then deduct "taxes linked to production" to obtain gross value-added (factor cost). For the United States in 1989, subsidies were $9.4 billion and taxes were nearly $4.7 billion in these accounts (OECD, 1991).

In the national income accounts, the value of the use of the operators' farm dwellings is included as part of value-added in the farm sector. It has been difficult historically to separate the value of the operator's house from the rest of farm real estate (USDA, 1988). More than a million farms produce less than $10,000 in gross sales. Net value-added on many of these farms is negative or close to zero except for the rental value of the house, which in many cases is higher than the value of agricultural sales. Excluding the rental value of operators' dwellings emphasizes the economic contributions arising from agricultural production, a truer measure of value-added.

Depreciable capital is used up in production over more than one time period. The difference between *gross value-added* and *net value-added* is that net value-added includes a charge made for depreciation and obsolescence. Because net value-added more adequately reflects the true addition to the value of output than does gross value-added, our analysis is based on the "net" concept, that is, after a charge for the operator's estimated depreciation. Because this analysis is based on farm record data, the depreciation estimates are in large measure those made for tax purposes, and not what would have been ideal, that is, economic depreciation based on replacement value.

Rent as payment for the use of agricultural land can be either on a share or a cash basis. In the U.S. national income accounts, agricultural land not owned by a farm operator is considered part of the real estate sector, not agricultural production. In the FCRS summaries, all agricultural land used for farming, regardless of ownership, is considered part of the farm sector. Since more land is being rented by farm operators (225 million acres in 1969 compared with 338 million in 1988) (U.S. Dept. Commerce, 1990), rental payments, received or paid, are considered in calculating net value-added.

Farm businesses regularly buy such services as artificial insemination, aerial spraying, and accounting. In the U.S. national income accounts, labor is considered as net value-added to agriculture if the payments are made directly to individual workers. Contract labor, however, is not considered net value-added because the service is hired through a crew boss, even though these services are almost exclusively directed to production agriculture. Consequently, contract services are treated here like a purchased input that creates value-added for the services sectors.[3]

Net Value-Added and the Size Distribution of Farms

The most common method of examining the size distribution of farms in the United States is by gross sales class (table 1).[4] The 34,000 largest farms with sales of $500,000 or more in 1989 made up 2 percent of farms, 33 percent of gross cash income, and 41 percent of net cash income. By gross sales class, 31 percent of farms with sales of $40,000 or more accounted for 90 percent of gross farm income.

When net value-added is substituted for gross sales (table 2), the production gap between farms is even more dramatic. Some 504,400 farms with net value-added of $20,000 or more (29 percent of the total) accounted for 95 percent of the positive net value-added in the 1989 FCRS.

Nearly 35 percent of all farms recorded negative net value-added in 1989. Twenty-nine percent of these farms had net value-added between minus $1 and minus $9,999. Of greater interest, more than 100,000 farms with net value-added of minus $10,000 or less reduced the value of the sector's contribution to the economy by 7 percent. These less productive farms call attention to the contrasts and variability within the farm sector. Some large farms with net value-added of $500,000 or more (about 17,000) accounted for 35 percent of the sector's total net value-added. Another group of 26,000 farms at the other end of the distribution erodes almost 5 percent of the total. Size by itself does not ensure positive returns.

Just under 1 million of the 1.73 million farms showed net value-added between minus $10,000 and $10,000. The majority of these farms are operated by individuals whose primary source of

[3]It can also be argued that specialized agricultural services should be recognized as a separate component of the services sector and then considered as part of the larger food and agricultural industry.

[4]Gross sales data are based on values of all commodities removed from an operating farm but include both the operator's and the landlord's shares. This is true for statistics from USDA and the Bureau of the Census.

Table 1—Distribution of farms by sales class, FCRS data, 1989

Sales class	Farms		Gross cash income	Net cash income
	Number		*Percent*	
$500,000 or more	34,318	2.0	33.4	40.9
$250,000 to $499,999	67,,608	3.9	18.3	21.0
$100,000 to $249,999	192,870	11.1	25.0	30.8
$40,000 to $99,999	236,834	13.7	13.2	13.7
$20,000 to $39,999	180,040	10.4	4.7	2.7
$10,000 to $19,999	214,335	12.4	2.7	–0.7
Less than $10,000	808,809	46.6	2.8	–8.4
Total	1,734,800	100.0	100.0	100.0

family income does not come from commercial agriculture. But, where farming is their primary business or where farm operations generate annual sales of $50,000 or more, it would be useful to know more about the small margins and lack of value-added. Relative inefficiency may result from bad weather, natural disaster, or ill health, or it may reflect endemic problems: poor management, cash-flow problems related to high debt-to-asset ratios, or uncompetitive physical resources.

The 163,500 farms with net value-added of $100,000 or more in 1989 accounted for 79 percent of aggregate, net value-added (table 2). Average gross income per farm (operators cash income plus the value of inventory changes, and landlord and contractor shares) was large for each of these three classes (table 3). Average gross income for each of the classes provides additional perspective on the scope of these businesses. Farms with small value-added, either negative or positive, typically had small gross income. For the 35 percent of the farms with negative net value-added, most had gross income of $20,000 or less. But farms with the largest negative value-added, –$30,000 or less, had substantial gross income, averaging $147,000.

Further analysis of the 45 percent of all farms that had net value-added between $4,999 and minus $4,999 indicated that all but 5 percent of these farms had gross income of $20,000 or less. The small net value-added was primarily a function of the size of their business activity and associated lack of operating efficiency.

Net value-added on each farm was expressed as a percentage of gross farm income. The average percentage for each of the size classes is presented in table 3. In general, the larger size intervals for net value-added also had the highest average percentages, but there was an important amount of variability within each class interval. The average for all farms, 44 percent, is an average of totals—total net value-added for all farms divided by total gross income. Farms with value-added in the interval, $40,000-$99,999, at 43 percent,

Table 2—Farm numbers by net value-added, FCRS data, 1989

Net value-added class	Farms		Percent of net value-added
	Number	*Percent*	
$500,000 and over	16,900	1.0	35.2
$250,000 to $499,999	29,900	1.7	15.6
$100,000 to $249,999	116,700	6.7	28.0
$40,000 to $99,999	183,100	10.6	18.0
$20,000 to $39,999	157,800	9.1	7.1
$10,000 to $19,999	129,900	7.5	2.9
$5,000 to $9,999	126,800	7.3	1.4
0 to $4,999	368,900	21.3	1.1
–$1 to –$4,999	404,600	23.3	–1.2
–$5,000 to –$9,999	98,400	5.7	–1.1
–$10,000 to $19,999	52,200	3.0	–1.2
–$20,000 to –$29,999	23,400	1.3	–0.9
Less than –$30,000	26,200	1.5	–4.9
Total	1,734,800	100.0	100.0

closely approximated the average for the sector as a whole.

Negative percentages occurred on about 35 percent of the farms. Most of these are small businesses. Nevertheless, for the 5 percent with somewhat larger operations, it reflects an important negative reality that can be expected as one part of the structural dimensions of the farm sector.

Cumulative Distributions

A comparison of the size distributions of farms for value-added and gross farm income is presented in figure 1.[5] Two cumulative frequency distributions are compared for farms in the 1989 FCRS. The distribution for net value-added has an important negative component while gross farm income starts at 0. The two distributions are nearly contiguous in the 20- to 40-percent range. There is a much wider range of values, however, for gross farm

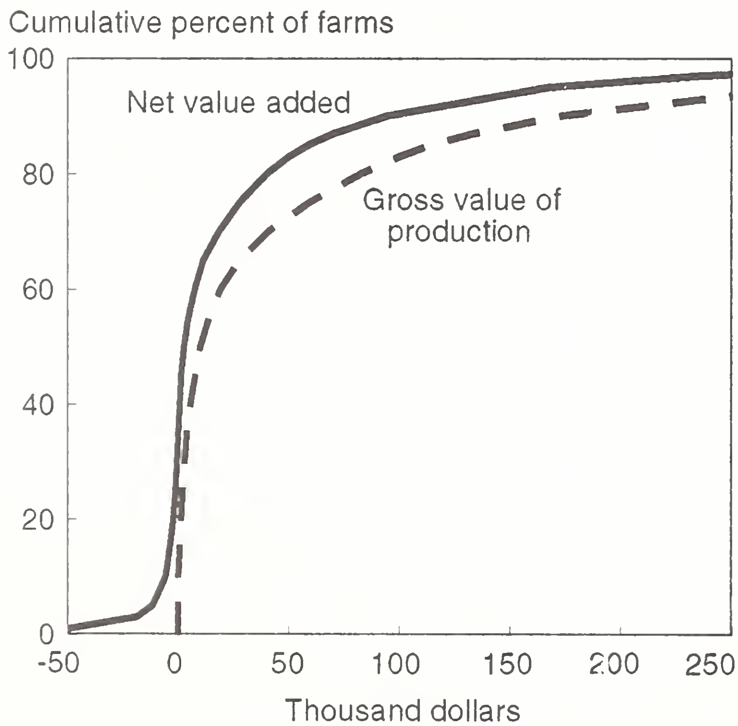
[5]Gross value of production is used as a proxy for gross farm income in this figure. The two distributions are virtually identical when plotted graphically.

Table 3—Relationship of net value-added to gross farm income per farm, FCRS data, 1989

Net value-added class	Farms	Average gross farm income	Net value-added as portion of gross farm income
	Number	*Thousand dollars*	*Percent*
$500,000 and over	16,900	2,000	66
$250,000 to $499,999	29,900	607	56
$100,000 to $249,999	116,700	300	52
$40,000 to $99,999	183,100	147	43
$20,000 to $39,999	157,800	73	40
$10,000 to $19,999	129,900	41	35
$5,000 to $9,999	126,800	25	30
$0 to $4,999	368,900	10	19
–$1 to –$4,999	404,600	5	–37
–$5,000 to –$9,999	98,400	12	–61
–$10,000 to –$19,999	52,200	20	–71
–$20,000 to –$29,999	23,400	30	–81
Less than –$30,000	26,200	147	–83
Total	1,734,800	85	44

Figure 1

Cumulative distribution of farms, by net value-added and gross value of production



Source: 1989 Farm Costs and Returns Survey, USDA

income than for value-added in the range where 40-80 percent of the farms are located. The upper tail of gross farm income extends beyond that of net value-added. Figure 1 shows the large percentage of farms to be in the middle range for net value-added (minus $5,000 to $50,000).

Net Value-Added by Type of Commodity Specialty

One of the problems with using gross sales as a measure of size of business in agriculture is the substantial amount of double-counting that occurs when a large proportion of those sales results from buying much of what is sold from other farmers. An example of this is livestock operations, which feed out animals purchased from other farmers. When considering structure questions or making comparisons across different types of farms, a size distribution based on net value-added will allow more appropriate evaluations of the differences observed.

Crops

Table 4 gives an indication of the importance of differences in net value-added for various types of farms. Types of farms are ranked by the percentage that net value-added makes up of gross farm income. Thus, vegetable farms, where gross farm income came primarily from vegetables, had the highest ratio of value-added, 63.7 percent, in 1989. These are generally large farms, where hired labor is a major component of costs and hence a major contributor to net value-added. Some of the same logic holds for other types of farms with higher percentages: greenhouse and nursery, sugar, rice, and cotton. Tobacco also requires substantial amounts of hired labor, but smaller enterprises are the general rule.

Cash grain enterprises are less labor intensive. Other cash grains (no dominant enterprise), corn, wheat, and other field crops use less labor and include a high proportion of farms with net value-

Table 4—Net value-added by type of farm, FCRS data, 1989

Type of farm[1]	Farms[2]	Mean value-added[2]	Portion of farms with net value-added of $25,000 or more	Net value-added as portion of gross income
	Number	*Thousand dollars*	*Percent*	
Crops:				
Vegetables	21,100	213	50	63.7
Other cash grain	17,400	69	29	63.1
Greenhouse, nursery	24,300	126	38	62.0
Sugar	3,300	193	82	58.1
Tobacco	53,000	20	16	56.9
Corn	84,900	64	51	54.9
Rice	3,200	122	80	53.1
Cotton	13,300	153	72	53.0
Fruit, nuts	58,700	51	26	49.6
Other field crops[3]	121,400	67	56	48.1
Wheat	54,600	36	38	47.4
Soybeans	63,300	23	26	45.6
Peanuts	7,000	45	57	42.5
Hay, forage	104,800	8	7	38.2
Unclassified	186,200	5	4	46.2
Livestock:				
Cow-calf	496,400	20	14	49.7
Poultry	33,500	163	56	42.5
Dairy	140,000	65	64	38.7
Other livestock	80,700	21	22	30.8
Hogs	74,600	23	25	27.9
Sheep, wool	27,100	4	3	18.5
Fed cattle	65,900	29	21	15.5

[1]Type of farm classified on the basis that 50 percent or more of the value of production comes from that commodity.
[2]Numbers rounded to facilitate comparisons.
[3]Includes farms where no single crop like sugarbeets, soybeans, peanuts, cotton, tobacco, or potatoes accounted for 50 percent of the value of production.

added between $10,000 and $100,000. Soybeans and peanuts also have similar characteristics.

In contrast, hay and forage includes a large number of small units where it is likely that off-farm income is the primary source of family income. A large number of "unclassified" farms (10.7 percent of the total) are primarily made up of operations with small gross incomes.

Livestock

More than 28 percent of all farms were classified as cow-calf operations and 8 percent as dairy farms. An indication of their structural dispersion is provided in this frequency distribution:

Net value-added	Cow-calf farms	Dairy farms
–$10,000 or less	28,600	5,400
–$5,000 to –$9,999	33,000	3,200
–$1 to –$4,999	144,100	3,200
$0 to $4,999	137,500	6,700
$5,000 to $9,999	41,800	5,400
$10,000 to $24,999	43,700	20,200
$25,000 and over	67,600	89,200

Most of the cow-calf enterprises are small in terms of net value-added. While some enterprises sustained losses, more than 110,000 farms had net value-added of $10,000 or more.

In contrast, dairy farms had a substantially different distribution. Most of these farms furnished employment for more than one worker. More than 75 percent of the dairy farms had a net value-added of $10,000 or more. In general, the ratio of value-added to gross income rises as farm size increases, more labor is employed, and less purchased inputs are used per unit of gross income.

Fed cattle and sheep and wool farms are at the other end of the distribution in terms of value-added per unit of gross income. Purchases, both animals and feed, make up a much larger proportion of every dollar of gross income for fed cattle. In the case of sheep and wool farms, small enterprises on part-time farms account for most of the numbers and the relatively low ratio. About 1,000 sheep and wool farms showed a net value-added of $25,000 or more, where value-added per

dollar of gross income was about 50 percent, more nearly like cow-calf operations.

Stability of Net Value-Added to Gross Income by Type of Farm

Similar ratios were calculated using the FCRS data sets in 1987 and 1988 with a somewhat different methodology for classifying types of farms and less complete data for landlord expenses and contract items. For some types of crop farms, like greenhouse and nursery, the stability across 3 years is surprisingly constant (64, 66, and 62 percent), as it was for cotton (55, 53, and 53 percent). For others, like wheat, there is substantial variation (58, 67, and 47 percent). The differences in prices received during 1987-89 explain an important part of the year-to-year variability.

The stability of the cow-calf ratios over the 3 years was also significant (47, 49, and 50 percent). Similar percentages calculated for dairy farms were also stable (41, 37, and 39 percent). Fed cattle generated the lowest numbers (8, 14, and 16 percent) in each of the years. The numbers for poultry and hogs were more variable, in part related to changing prices received in the different years.

If one wants to find a common denominator in looking at the size distribution of businesses in a State or region, these ratios of value-added to gross income provide a rough method of calculation (Purcell, Eddleman, Kunz, 1982). Thus, one could recognize that $1 million of gross income from fed cattle is about equal to $245,000 of gross income from vegetables in terms of value-added ($1 million × 0.155 = $155,000, and $245,000 × 0.637 = $156,000). In a similar manner, $400,000 of gross income on a dairy farm equals $1 million of gross income for fed cattle in value-added terms.

Aggregate Value-Added by Type of Farm

Aggregate output from the farm sector can be effectively described in terms of value-added by type of farm and commodity specialty (table 5). All the FCRS farms were included in one or another of the commodity classifications. Cow-calf and dairy have the two largest aggregates, followed closely by "other field crops." The calculation of net value-added increases the relative importance of crops compared with an equivalent table based on the value of sales. Vegetable, greenhouse and nursery, and fruit and nut farms gain greater visibility among farms where crops are central to production.

The various types of farms classified as primarily crops accounted for $34 billion, 52.6 percent of the sector aggregate. Livestock farms provide $29.7 billion, nearly 46 percent. The unclassified farms make up the other 1.5 percent. Net value-added puts the contributions of the different types of farms into an economic context where returns to land, labor, capital, and management are emphasized.

Table 5—Aggregate value-added by type of farm, FCRS data, 1989

Type of farm	Farms	Aggregate net value-added
	Number	*Million dollars*
Cow-calf	496,400	9,684
Dairy	140,000	9,107
Other field crops	121,400	8,142
Corn	84,900	5,453
Poultry	33,500	5,451
Vegetables	21,100	4,494
Greenhouse, nursery	24,300	3,050
Fruit, nuts	58,700	2,979
Cotton	13,300	2,042
Wheat	54,700	1,966
Fed cattle	65,900	1,890
Other livestock	80,700	1,725
Hogs	74,600	1,721
Soybeans	63,300	1,461
Other cash grain	17,400	1,208
Tobacco	53,000	1,056
Unclassified	186,200	974
Hay, forage	104,800	864
Sugar	3,300	633
Rice	3,200	390
Peanuts	7,000	313
Sheep, wool	27,100	117
Total	1,734,800	64,720

Relative Importance of Type of Farm by Gross Sales and Value-Added

Value-added provides a different relative ranking for different types of farms compared with one based on gross sales (table 6). On most livestock farms, except for cow-calf operations, gross sales yield a higher relative ranking or suggest greater importance than does value-added. Value-added emphasizes net additions to output. Purchased feed and purchased feeder animals are deducted from gross income in calculating value-added. Therefore, for farms that specialize in fed cattle, the difference between gross sales and value-added is substantial. In contrast, for cow-calf operations, where purchased inputs are relatively much smaller, the value-added measure increases the rank in percentage terms. For most crop farms, value-added consistently increases the relative rankings (table 6).

Table 6—Impact of the value-added measure on relative ranking of selected types of farms, FCRS data, 1989

Type of farm	Percent of aggregate value for United States	
	Gross sales	New value-added
	Percent	
Livestock:		
Cow-calf	12.4	15.0
Dairy	16.0	14.1
Fed cattle	8.8	2.9
Hogs	4.6	2.7
Crops:		
Other field crops	11.1	12.6
Corn	6.4	8.4
Vegetables	5.0	6.9
Wheat	2.4	3.0

Conclusions

Net value-added provides a more accurate economic assessment of the relative importance of individual farms and types of farming than traditional approaches. Size of business as measured by net value-added is described in terms of what has been added to economic output as a result of business operations. It calls attention to investments in the productive resources of farming—wages, interest, rent, and management return.

More attention directed to estimating value-added from farming, and its distribution across farms, will provide policymakers with useful information for understanding how changing conditions will affect different types of farm businesses in the context of national and local economies. More specifically, as a measure of farm size, net value-added insures that inventory adjustments are considered, government payments are recognized where appropriate, and the contributions of firms with large amounts of purchased agricultural inputs are treated in a fashion similar to other types of producers. For example, the very large sales per farm or ranch of a number of fed cattle operations are more accurately assessed because purchases of feeder cattle and feed are deducted in calculating net value-added. Crop farms increase in relative importance in terms of their contribution to sector returns to resource use. Most livestock farms command less of the aggregate for net value-added than for gross income or gross sales. Greater visibility given to value-added rather than gross sales or net farm income will enhance public understanding of economic contributions from agricultural production.

References

Baumol, W.J., and A. Blinder. 1979. *Economic Principles and Policy*. New York: Harcourt, Brace, Jovanovich, pp. 322-23.

Brinkman, G.L. 1989. *Structural Change in Canadian Agriculture in the 1980s.* Agriculture Canada.

Farm Accounting Data Network. 1986. *Farm Account Results, 1982/83-1983/84.* Commission of the European Communities, Luxembourg, p. 150.

Hanson, G.D., B.F. Stanton, and M.C. Ahearn. 1989. *Alternative Measures of Farm Output to Classify Farms by Size.* TB-1749. U.S. Dept. Agr., Econ. Res. Serv.

Hayami, Yujiro, and S. Yamada. 1991. *The Agricutural Development of Japan: A Century's Perspective.* Tokyo: University of Tokyo Press.

Jinkins, John, and Mary Ahearn. 1991. "Net Value-Added Gauges Farming's Contribution to the Economy," *Agricultural Outlook.* AO-174.

McLeay, Stuart. 1983. "Value-Added: A Comparative Study," *Accounting, Organization and Society.* Vol. 8, No. 1, pp. 31-56.

Meek, Gary K., and S.J. Gray. 1988. "The Value-Added Statement: An Innovation for U.S. Companies," *Accounting Horizons,* pp. 73-81.

Morley, Michael F. 1979. "The Value-Added Statement in Britain," *The Accounting Review.* Vol. LIV, No. 3, pp. 618-29.

Murphy, M.C. 1989. *Report on Farming in the Eastern Countries of England, 1987/88.* University of Cambridge, England.

Organization for Economic Cooperation and Development. 1991. *Economic Accounts for Agriculture, 1976-89.* Paris.

Outlaw, J.E., and G. Croft. 1982. "Recent Developments in Economic Accounts for Agriculture," *Annual Review of Agriculture.* Ministry of Agriculture, Forestry, and Fisheries, United Kingdom.

Purcell, J.C., B.R. Eddleman, and J.J. Kunz. 1982. *Investment in Production-Related Research Relative to Value-Added in United States Agriculture.* SAES, IR-6 Info. Report 63. U.S. Dept. Agr., Coop. State Res. Serv.

U.S. Department of Agriculture, Economic Research Service. 1991. *Economic Indicators of the Farm*

Sector: National Financial Summary, 1989. ECIFS 9-2.

U.S. Department of Agriculture, Economic Research Service. 1988. *Major Statistical Series of the U.S. Department of Agriculture, Volume 3: Farm Income*. AH-671.

U.S. Department of Commerce, Bureau of the Census. 1990. *Agricultural Economics and Land Ownership Survey*. 1988. AC87-RS-2.

U.S. Department of Commerce, Bureau of the Census. 1985. "An Introduction to National Economic Accounting," *Survey of Current Business*, pp. 59-76.

Appendix table 1—Calculation of net value-added averages, all specialized wheat farms, FCRS data, 1989

Description	Average per farm
	Dollars
Gross farm income:	
Commodity sales of farming operation	47,605
Changes in inventory	5,155
Government payments	11,947
Value of home consumption of farm products	176
Farm-related income	4,256
Value of commodities produced under production contracts	72
Value of share rents	8,592
Total	77,803
Deductions, except compensation to labor, taxes, interest, and rent	41,822
Gross farm income – deductions = net value-added	35,981

Karl Fox: A Retrospective

Economic Models, Estimation, and Socioeconomic Systems: Essays in Honor of Karl Fox. *Edited by T.J. Kaul and J.K Sengupta. Amsterdam: North-Holland, 1991, 645 pages, $89.50.*

Reviewed by Richard J. Foote

Editor's Note: Gene Wunderlich, former economics editor of *The Journal of Agricultural Economics Research*, once lauded Karl Fox's stature as an agricultural economist by writing: "The life and times of Karl Fox is a classic case for broad, varied training and experience. His personal story is a metaphor for a substantial portion of the profession. For Fox, doing agricultural economics meant continuing education, writing in theory, and analyzing a wide spectrum of applied economic problems."

A year or two after I returned to USDA from private industry in 1950, Karl Fox introduced me to econometric systems of simultaneous equations. For several fruitful years, he was my immediate supervisor. In 1952-53, I converted his award-winning Ph.D. thesis into a USDA technical bulletin and later administered a program inaugurated by him under which promising young university scholars researched new agricultural economics methodologies. This program yielded the application of expectational theory, like distributed lags, to the supply response of farmers (Marc Nerlove) and to new storage rules (Robert L. Gustafson).

This volume opens with "A Scientific Autobiography" (1986) which begins with Fox's career in college and charts developments that led to the relatively modern field of econometrics and to the new discipline of eco-behavioral science. A series of essays written by internationally known economists follows.

The first essay, by Gordon C. Rausser and David Zilberman of the University of California at Berkeley, presents a controversial conclusion. They predict that "conflicting interests can be expected to result in declining support for public research in agriculture" (p. 36). They suggest that the present system be replaced by research initiators who would submit proposals to research administrators at the Federal or State level. Failing this, the proposal would be submitted to the Public Research Commission made up of members appointed by elected State or Federal officials. Policies and decisions of the Commission should reflect "societal value judgments on equity across groups affected by the proposed research. The Commission would ... determine whether the program should be supported by the public sector and, if it should, to impose the final incidence of burden to support the research program" (p. 41). Each interest group would manage a reserve fund composed of dues to finance projects that benefit members and compensation payments for projects that harm members. Government agencies would represent diffuse interest groups such as consumers. The authors conclude: "The cost of implementing the above three-stage research evaluation design certainly compares favorably with the current use of the court system to resolve ex post conflict" (p. 45). They note that this "design keeps intact the superb land grant system of research and extension" (p. 46).

Glenn L. Johnson, Michigan State University, addresses not so much accounting but accountability by production economists. He questions their ability to research normative values in an objective, descriptive manner. The meaning attached to such terms as "product," "production," "input," and "efficiency" are examined within the context of theoretical and empirical work and applied to the evaluation of market adjustments when knowledge is imperfect or the government intervenes. Johnson then summarizes ideas published elsewhere on how work with normative dimensions can be done objectively.

James L. Seale, Jr., and Henri Theil of the University of Florida discuss demand analysis, and note that in the past several decades, consumer demand analysis has steadily moved toward a systemwide approach. In a number of algebraic specifications of demand systems, the authors consider first the income sensitivity and then the price sensitivity of demand. They emphasize matters of empirical validity rather than mathematical details. Since income elasticities vary over time, the authors strongly recommend that they be shown over time. For example, based on a translog model, Japanese income elasticities for food *increased* from 0.42 in 1951 to 0.75 in 1972. Based on Working's model, they *decreased* from 0.72 to 0.54 over the same period. For 1961, they are 0.61 and 0.64 for the respective models.

A rational expectations equilibrium model is put forth by E. Kwan Choi and Stanley R. Johnson of Iowa State University. This model shows how parameters of a price stabilization program affect

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producer participation and factor intensity. Risk premiums and factor use levels are aggregated and used to investigate the effects of changes in the policy parameters on market supply response and producer income. The authors maintain that an efficient stabilization program can be designed to maximize producer income for a given expected government cost. If the government has a fixed budget for stabilization, an efficiency analysis can determine commodity markets for government intervention.

An essay by Carl F. Christ from Johns Hopkins University details helpful steps to avoid pitfalls in macroeconomic model building. He states, "Many and varied are the inconsistent, incomplete, or inappropriate economic models I have encountered..." (p. 257). I heartily agree, based on my own experience. His paper should be read by anyone working in this area.

The papers summarized above illustrate the variety of material within this volume. Several of the papers under the heading "Socioeconomic Accounts, Models, and Systems" would be of interest to *JAER* readers as will Fox's autobiography and Harold F. Breimyer's "Transcendental Allegory." The book should be purchased by all libraries that serve economists, econometricians, mathematical statisticians, or sociologists. I recommend borrowing a copy from the library, reading material of interest, and then deciding whether to purchase a copy for more permanent use.

Use of bST in Dairy: Public Perception and Projected Response

Bovine Somatotropin and Emerging Issues. *Edited by Milton C. Hallberg. Boulder, CO: Westview Press, 1992, 324 pages, $44.50.*

Reviewed by W. Burt Sundquist

Much has been written on the topic of agricultural biotechnologies and, especially, bovine somatotropin (bST). This book is the best integrated treatment of bST anywhere. Along with a substantive foreword, the book contains 14 chapters authored or coauthored by 21 experts. This large gathering did produce some unevenness in exposition and some minor, but not particularly bothersome, duplication of subject matter. Moreover, a set of common assumptions greatly enhances the value of the information generated on the following topics: economic evaluation of bST for onfarm use, bST effects on aggregate and regional resource needs and on beef and veal output, and bST and the price of milk and dairy products.

The foreword and first part of the book "Biotechnology and Society," present a good review of biotechnology since the first successful directed insertion of foreign DNA into a host organism less than 20 years ago. Realized and expected applications of biotechnology for animals, plants, and food processing are described in some detail and potential scenarios are developed for science, for farmers and rural communities, for consumers, for agribusiness, and for international trade and development. In the process, the authors find a number of potential problems (unwanted effects of biotechnology) and plead for effective *ex ante* evaluations of each of the significant emerging technologies. They conclude that, "Biotechnology now permits the design of future agricultural systems without providing any guidance for the directions of technology development and the assessment of embedded social choices." Among the ethical questions identified is how to "deal effectively with technical questions of responsibility, social justice, and human (and animal) well being?" A simple solution might be to build a higher wall between public science (public research institutions), which is generally held in a position of public trust, and private science (private corporations), which develops technologies that may produce unwanted consequences. But this solution is thought unworkable because of the extensive interdependence of public and private institutions in financing and conducting research. Also, public confidence in the credibility of public research has declined, further complicating the situation. In the meantime, uncertainty persists among dairy farmers and consumers about the expected benefits (and possible unwanted consequences) of bST.

In the chapters on performance and management of bST-supplemented cows, extensive experimental evidence supports the conclusions that (1) a 10-20 percent boost in milk yields is achieved with 5-10 percent less feed per unit of milk, (2) the milk increase is greater for multiparous cows than for heifers, (3) high environmental temperatures and relative humidity can reduce yield response, and (4) progressive farmers employing best-management practices (including balanced rations, effective health program management, high-quality forages, advanced production-monitoring, and farm-cost ac-

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counting records) appear to have the greatest potential to optimize profits from bST use.

In the chapter on economic evaluation of bST for onfarm use, effective illustrative procedures are presented that can be used to examine the farm-level net revenue associated with use of bST. Net revenues are calculated for cows with differing genetic capabilities and response rates and with alternative price levels for bST and milk. These are all key variables in determining the profitability of bST use for the individual dairy farmer.

Milk market implications of bST adoption are based on a set of economic models that utilize a milk supply and consumption data base for each of 16 U.S. subregions and 8 regions. Milk supply elasticities differ between most subregions, whereas a common set of demand elasticities is assumed for all subregions. A spatial equilibrium model is then used to determine producer milk prices, regional milk supply/marketings, consumer expenditures, producer revenues, and cow number requirements under a set of scenarios which, in addition to the base run (no bST), include (1) bST adopted everywhere, (2) bST banned in the Midwest, (3) bST banned in the Northeast, and (4) bST adoption with reduced milk consumption (in response to negative consumer reaction to bST). Estimates of feed and labor requirements and veal and cull cow production are generated using a separate (per cow) cost-and-return, budget-based set of computations.

At the risk of oversimplification, one can summarize the national-level results of full bST adoption with baseline milk consumption requirements as follows:

(1) Producer milk prices, –8 percent;
(2) Dairy cow numbers, –7 percent;
(3) Milk marketings, +2 percent;
(4) Labor hours required for milk production, –2 percent; and
(5) Hay and silage requirements, –6 to –7 percent.

Under the assumption of reduced milk consumption, milk prices would decline an additional 4 percent. Under scenarios where the use of bST was banned in one region but not in others, the banning region would suffer a decline in shares of milk production and marketings. Although the above model results are probably best used only as a broad gauge of the expected market, their directions and general magnitudes appear both consistent and reasonable.

A chapter on consumer responses to milk from bST-supplemented cows evaluates 11 separate studies on consumer perceptions. The results are not easily summarized but are consistent in that most consumers are concerned about bST. Eight studies indicated that, on average, about 60 percent of respondents would not change consumption if milk were produced with bST. The other 40 percent believed they would respond by decreasing or ceasing milk consumption.

The book also contains substantive chapters on bST and animal health, potential adoption and diffusion of bST, effects on small versus large dairy farms, food safety and product quality, bST and international trade and policy, and a final summary of issues, facts, and controversies. A very brief perspective of expected bST impacts gained from these chapters is that (1) animal health problems can generally be handled with good management practices, (2) bST adoption will be lowest on smaller dairy farms and among younger and older farmers, (3) milk from bST-treated cows is a safe food product no different from milk cows not receiving bST, and (4) a growing demand for food quality in developed countries will likely result in a proliferation of differing food quality standards, which will create significant barriers to trade.

A number of countries have already approved the use of bST, although a moratorium on its use is still in effect in the European Community. And, with or without bST, U.S. milk production per cow will continue to increase. What then should be the public policy response to bST? Hallberg suggests developing policies aimed specifically at easing the adjustment process. This would contribute to general economic growth and progress while lessening the imperative to provide specific protection from a given technology.

The book is very well organized and well written, identifying and discussing the major issues voiced about bST. It does not provide a quantitative aggregation of potential benefits or unwanted consequences of bST, but it couldn't. The book is a very useful prototype for the broad-based technology assessment studies that public research institutions should undertake.

Searching for Appropriate State Intervention

Agriculture and the State—Growth, Employment, and Poverty of Developing Countries. *Edited by C. Peter Timmer. Ithaca, NY: Cornell University Press, 1991, 312 pages, $45.*

Reviewed by Gene Mathia

The setting and timing must have seemed propitious for a discussion of how governments of developing countries intervene in the agricultural development process and what approaches seem to work. The role of the state in agriculture was the topic of a conference in August 1989 in Switzerland's Marbach Castle.

The conference coincided with the beginning of the collapse of several governments in countries with very strong central planning authority. The fall of the Berlin Wall and the demise of several Eastern European governments seemed to have tempered the discussion of government's role in the development process. Heard were such comments as "agricultural development would go better without the government" and "the state can be trusted with nothing but defending the border." However, this view evidently gave way to support for a more active government role. Some held the belief that "governments should provide public goods and correct important market failures" and questioned the premise that "free markets and minimal state intervention are the surest path to riches."

This book focuses on the success of common forms of government intervention and the historical precedent for defining the appropriate role of future government involvement. By way of introduction, Timmer defines the areas where there is general agreement in principle for productive government involvement in agriculture. Included among them are agricultural research, agricultural extension, irrigation investments, and marketing infrastructure. The more controversial areas are land tenure, farmer organizations, marketing boards, and price policy.

Peter Linert follows with a historical assessment of agricultural policies by evaluating nominal protection coefficients to test two observed patterns: "the developmental pattern—the more advanced the nation, the more its government favors agriculture, and the anti-trade pattern—governments tend to tax exportable-good agriculture and protect import-competing agriculture." Linert believes farmers increase their effectiveness in lobbying to gain widespread sympathy as the sector shrinks. The agricultural lobby continues to grow as farm operators and landowners see government as a sentry against unpopular price movements. He fails, however, to address the problem that plagues most developing-country governments, that is, the inability to finance and manage the economic growth.

Alberto Valdes makes a case for growth through agricultural exports, demonstrating the relative success of that strategy in selected countries. However, he and James Houck question the wisdom of the strategy if it is pursued by many countries simultaneously. Some of the more obvious concerns would be the promotion of exportable products at the expense of food crops in countries where people go hungry; the often painful macroeconomic reforms, especially exchange rates, essential to stimulating expanded export opportunities; and the required domestic reforms that mean an efficient incentive structure for both producers and consumers. The authors do not address the problem of an underlying cost structure in both producing and marketing export crops, an expensive proposition for many developing countries.

Peter Timmer examines the need for a development policy that would raise agricultural productivity and would strengthen various aspects of production. He argues for a strategy that would increase labor productivity through increased capital investment, introduction of new technology, and improved labor mobility. The implication is that raising labor productivity and wages in agriculture may be better accomplished by creating opportunities in the industrial and service sectors than by intervening in the agricultural labor market and holding labor on the farm.

The World Bank and other development institutions that finance government-sponsored rural development and food aid as development tools were the subject of three chapters. Successes and failures of rural development projects are reviewed. The important point was that successful rural development projects require a strong government commitment along with several essential supporting services of domestic institutions. Economic assistance through food aid, though, is a costly resource allocation and is not a good countercyclical element in the world food economy, that is, quantity of food aid is generously provided when world stocks are large and prices are low but scarce when world market

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conditions are tight and prices are high. Current and expected low food surpluses in the donor countries (recognizing the difficult problem of alleviating hunger in situations created by location and political unrest), and creating incentive problems in recipient countries lead to low expectations for an expanded food aid program. Food aid for emergency situations received a high mark, but using food aid for development projects and balance of payments support is controversial.

The final two chapters address government characteristics that enhance economic and agricultural development. Faaland and Parkson describe the basic constraints to effective government support in modernizing agriculture, including limited governing powers, short-term survivability, and political alienation. They conclude that "it is the totality of the government that provides continuity of government function." They express the view that it is undesirable for a strong and stable government to intervene in agricultural production decisions, marketing, and setting prices. Its attention can be more effective in providing infrastructure and improving market mechanisms. Of course, infrastructure development carries a high price tag, a burden for governments with problems raising revenues and selecting priorities.

The concluding chapter by Timmer furnishes some valuable insights into the potential role of the state. Turning his attention to the timing and scope of government involvement, he emphasizes the importance of economic growth to help solve problems otherwise considered distributional issues. He concluded that "redistribution without growth has powerful and negative incentive effects on the rural economy; the only way to reduce poverty and hunger is to raise labor productivity, employment, and real wages of unskilled labor." Analysts must address these problems of developing countries today: How can governments support agricultural development—when public funds are scarce? when there are competing and legitimate demands from other potential sectors? when international funding is not expected to increase greatly? when potential benefits of foreign trade are subject to international trade agreements like GATT?

The discussion of several development tools and approaches demonstrates that any one intervention will not likely succeed as an engine of growth. What will work is a mix of well-managed government programs which foster growth and allow for time for institutions to change and adjust to new guidelines and incentives.

The book should be useful to policymakers in the developing countries and the international development institutions by raising questions about probable success or failure of alternative policy actions. The limited presentation of data on empirical results, however, may constrain its usefulness as a research document.

The chapters include: (1) "The Role of the State in Agricultural Development" by C. Peter Timmer; (2) "Historical Patterns of Agricultural Policy" by Peter H. Linert; (3) "The Role of Agricultural Exports in Development" by Alberto Valdes; (4) "Observations on Export-Led Growth as a Development Strategy" by James P. Houck; (5) "Agricultural Employment and Poverty Alleviation in Asia" by C. Peter Timmer; (6) "Government-Sponsored Rural Development: Experience of the World Bank" by Graham Donaldson; (7) "Rural Development: Problems and Prospects" by Cristina C. David; (8) "Food Aid, Development, and Food Security" by Edward Clay; (9) "Food Aid? A Comment" by Walter P. Falcon; (10) "The Nature of the State and the Role of Government in Agricultural Development" by Just Faaland and Jack Parkson; (11) "Notes on Agriculture and the State" by Raymond F. Hopkins; and (12) "What Have We Learned" by C. Peter Timmer.

Food for Thought

Food Trends and the Changing Consumer. *By Ben Senauer, Elaine Asp, and Jean Kinsey. St. Paul, MN: Eagan Press, 1991, 385 pages, $39.95.*

Reviewed by Kuo S. Huang

What are the trends in American eating patterns and lifestyles? How are U.S. demographics changing and how will they affect food consumption? How do consumers view food product attributes, food safety, nutrition, advertising, and brands? This book provides a comprehensive, valuable resource for current information on these questions.

Demographic changes in an increasingly aging population, a more diverse ethnic mix, more women in the labor force, and more desire for convenient food all have a dramatic effect on consumer food

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demands. These demands create major implications for food retailers, distributors, processors, and farmers. This book gives a detailed look at the trends of population growth, ethnic diversity, regional differences, household composition, aging, education, income, and labor force participation. These demographic changes are useful indicators to project the pattern of future food consumption. Drawing from some empirical results of consumer behavior research, the authors examine in detail the influences of price, income, and socio-demographic factors on the types and amounts of food consumed.

The major nutritional concerns in the United States have been focused on the linkages between diet and major chronic diseases, such as heart disease, cancer, and stroke. In fact, the National Nutrition Monitoring and Related Research Act of 1990 calls for a 10-year comprehensive plan to provide timely information about the role and status of factors that bear on the contribution made by nutrition to the health of Americans. Hunger and poverty are a problem for millions of Americans. This book provides information about the specific nutrition and nutrition-related health problems of the poor, and the major government food assistance programs, such as the Food Stamp Program and the National School Lunch Program. Also, the chapter on the American diet furnishes current trends in eating patterns, dietary recommendations, and attitudes.

Attention to food safety has increased significantly due to recent highly publicized incidents such as salmonella contamination in poultry, aflatoxin in grains, Chilean grape tampering, and Alar-tainted apples. The importance of food safety issues has been reflected in various public debates and government initiatives to collect data and provide information useful in addressing these problems. This book provides an overview of major food safety concerns and the issue of safety from a conceptual perspective. The basic food safety legislation in the United States and the policy formulation process are briefly reviewed. The book also covers several food safety topics of particular current interest, including pesticide residues, food-borne pathogens, seafood inspection, food additives, and safety concerns related to new technologies.

In general, this book is well written for those who would like to have a general idea about consumer trends, food consumption, nutrition, and the food industry. For government policymakers and regulators who monitor food and the food industry, the book is a useful reference source, particularly for food safety and other food and nutrition policy issues. For researchers, the book serves best as an introduction to food economic research, but the methodology issues are hardly explored. The chapter on reviewing the major sources of time-series data and cross-sectional data for food consumption and expenditures for the United States is very helpful for researchers to identify available data sources. Various sources of basic data, both government and private, on food expenditures and consumption are discussed, including methods used to collect data and their characteristics, accuracy, uses, and limitations.

One Vote for Doering's Call for Nonmarginal Analysis

Gerald F. Vaughn

This is in support of Otto C. Doering's article "Looking Back While Going Forward: An Essential for Policy Economists" (*JAER*, Vol. 43, No. 1). He asserts that marginal analysis is best suited to a stable economy or society. Doering believes that the U.S. and world systems are beyond stability, rendering marginal analysis less helpful, and that the development of nonmarginalist economics should accelerate to meet the needs of public policy. I agree with this call for nonmarginal analysis.

Robert B. Carson, in his book *What Economists Know*, even more sharply criticizes both the economics profession and policymakers. He writes: "... in the 1970s and 1980s, when there was much to be done, practically nothing of useful and lasting consequence was accomplished—not in terms of important theoretical and critical work nor in terms of policymaking" (p. 8). Nonmarginal analysis would contribute in ways that Carson desires.

For nonmarginalist economics to be useful to governments, public policymakers and program managers first must be receptive to it. And, that acceptance depends on what type of government is in office.

Richard J. Stillman II, who examines public administration, places government into four models: negative-state (or no-state), bold-state, pre-state, and pro-state. Negative-state is characterized by a sharply limited role for government (monetarists and public choice theorists), bold-state by a broadly expanded role (institution builders), pre-state by traditional norms typical of governments before World War II, and pro-state by technocracy (government by professional public administrators and scientific experts) typified by governments since 1945. In both pre-state and pro-state, change occurs in small increments at the margin.

Only negative-state and bold-state, which are departures from the trend, have shown a receptiveness to nonmarginalist economics, and neither of the two prevails except in a crisis. That is, when government seems too wasteful or intrusive, the negative-state gains ascendancy for a time. When government needs a stronger hand in depression or war, the bold-state presides.

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Nonmarginal analysis and action are most likely to be needed and to happen during a crisis. Agricultural economists can expect nonmarginalist economics to be best received at such times. John J. Gargan in *Handbook of Public Administration* observes:

> "Policy problem solutions drawn from Public Choice theory—privatization, vouchers, and voluntary initiatives—were applied by local, state, and national government during the 1970s and 1980s, partly because of the pressure on public finances, but also because of the availability of the solutions" (p. 1,004).

As Dr. Doering points out, during the 1930's and New Deal experimentation, USDA not only was receptive to, but was in the vanguard of, thinking of rural social scientists as reformers in farm policy (pp. 4-5).

Apart from times of crisis, government will tend to be in the pre-state or pro-state models, where change usually occurs at the margin. Agricultural economists working in or closely with government should not expect that nonmarginalist thinking will be accepted or prove useful between crises. Though cast in relation mainly to the Federal Government, the principle is the same for State and local governments.

What should nonmarginalists do, given these conditions? Kenneth Boulding, in *The Impact of the Social Sciences,* reminds:

> "Economists ... are not altogether guiltless of presuming to know more than they do and of giving advice when they should have been doing research" (p. 50).

Nonmarginalist agricultural economists should concentrate, therefore, on doing research (especially high-quality empirical studies) that will be ready and useful if and when advice is wanted.

Bibliography

Boulding, Kenneth E. 1966. *The Impact of the Social Sciences*. New Brunswick, NJ: Rutgers University.

Carson, Robert B. 1990. *What Economists Know: An Economic Policy Primer for the 1990s and Beyond.* New York: St. Martin's.

Gargan, John J. 1989. "The Public Administration Community and the Search for Professionalism," *Handbook of Public Administration.* Jack Rabin, W. Bartley Hildreth, and Gerald J. Miller (eds.). New York: Marcel Dekker.

Stillman, Richard J., II. 1991. *Preface to Public Administration: A Search for Themes and Direction.* New York: St. Martin's.

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